Iowa State University
Institute for Transportation

March 2024 MPO-RPA Quarterly Meeting

March 19, 2024

Trail Management Program

Des Moines Area MPO
Metropolitan Planning Organization

Introduction

- Trail management program is required to preserve the existing trail network.
- Create an inventory of condition data.
- Develop a data collection and assessment system suited to extensive trail network.

Source: 2018 Central Iowa Trail Condition Report

Iowa Data-bike

Develop a bike-based data collection vehicle
to improve the efficiency of collecting data on the
extensive trail network.

iPhone

Go Pro Camera

360 camera

Source: Central Iowa Trail
Condition 2019 Report

What Data Bike Collects?

Go Pro Camera

iPhone + SensorLog App

- Accelerometer readings
- Gyroscope readings
- Magnetometer reading

Trail smoothness

Reference Profiler

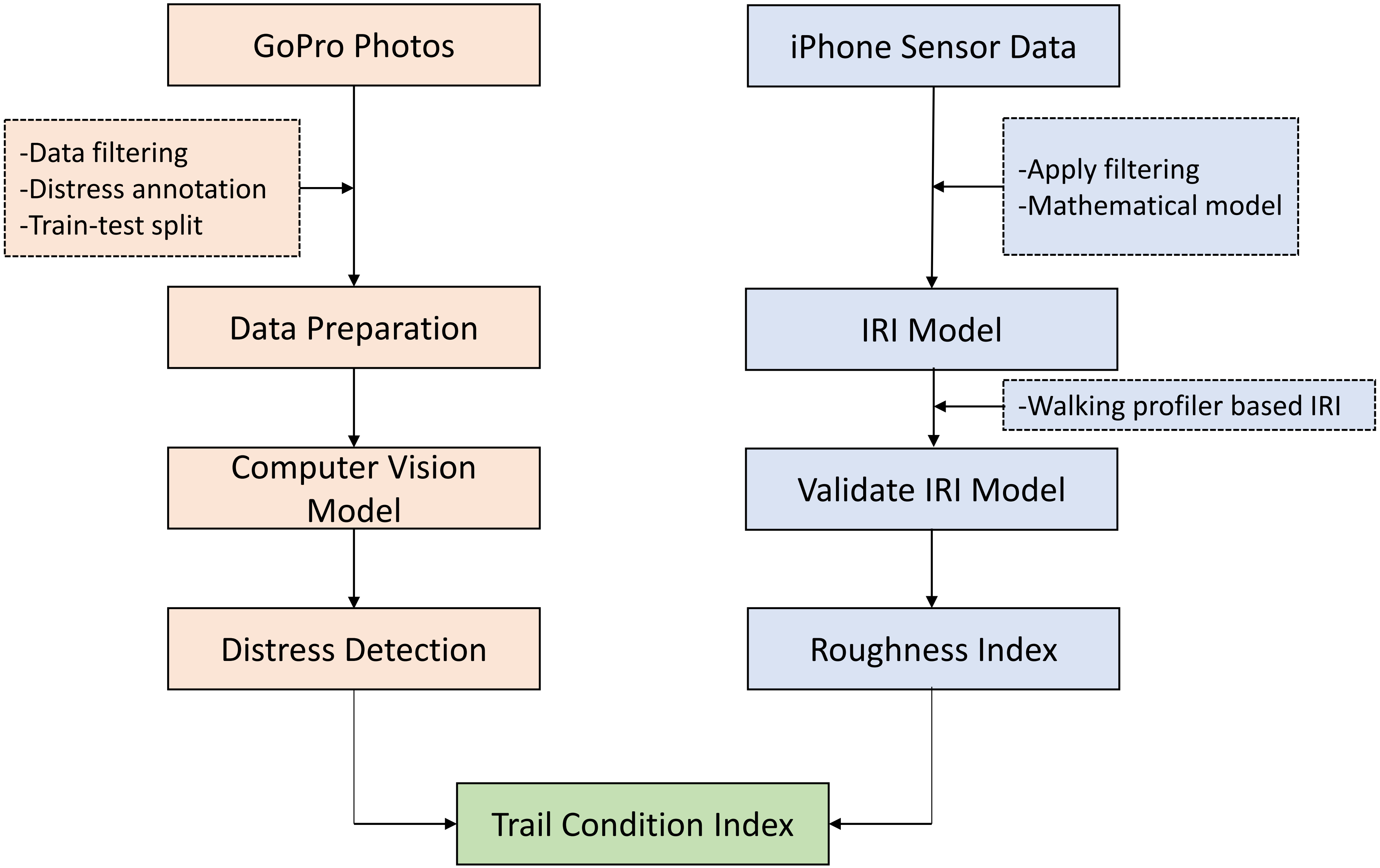
- Used as reference to the roughness measurements
  - To calibrate inertial profiler measurements.
- The device registers the longitudinal measuring profile of the pavement surface
  - by continuously lowered metal foot and for each measuring section reregisters the summed height in relation to the initial point.
- Measure surface roughness
  - Expected accuracy **~ 94-99%** depending on the walking speed



Photo courtesy: InTrans Team

Source: Roughness of the motorway driving surface (2010)

Phase-I Workflow



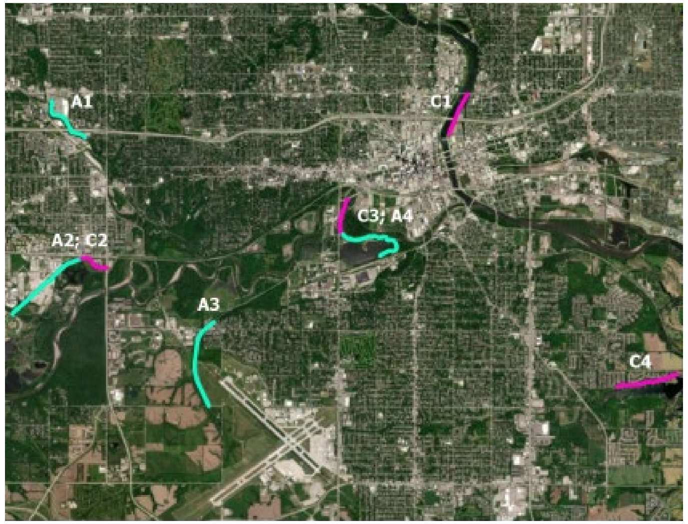
Data Collection Program

Control Site Selection

❖ Criteria for Site selection
- ✓Geographic spread
- ✓Region type- regional/local, urban/rural
- ✓Condition range- Very good to very poor

❖ Description of the sites selected:
- ✓ Length: 0.3 mile
- ✓ # of Asphalt surface (AC) sites: 04
- ✓ # of Concrete Surface (PCC) sites: 04

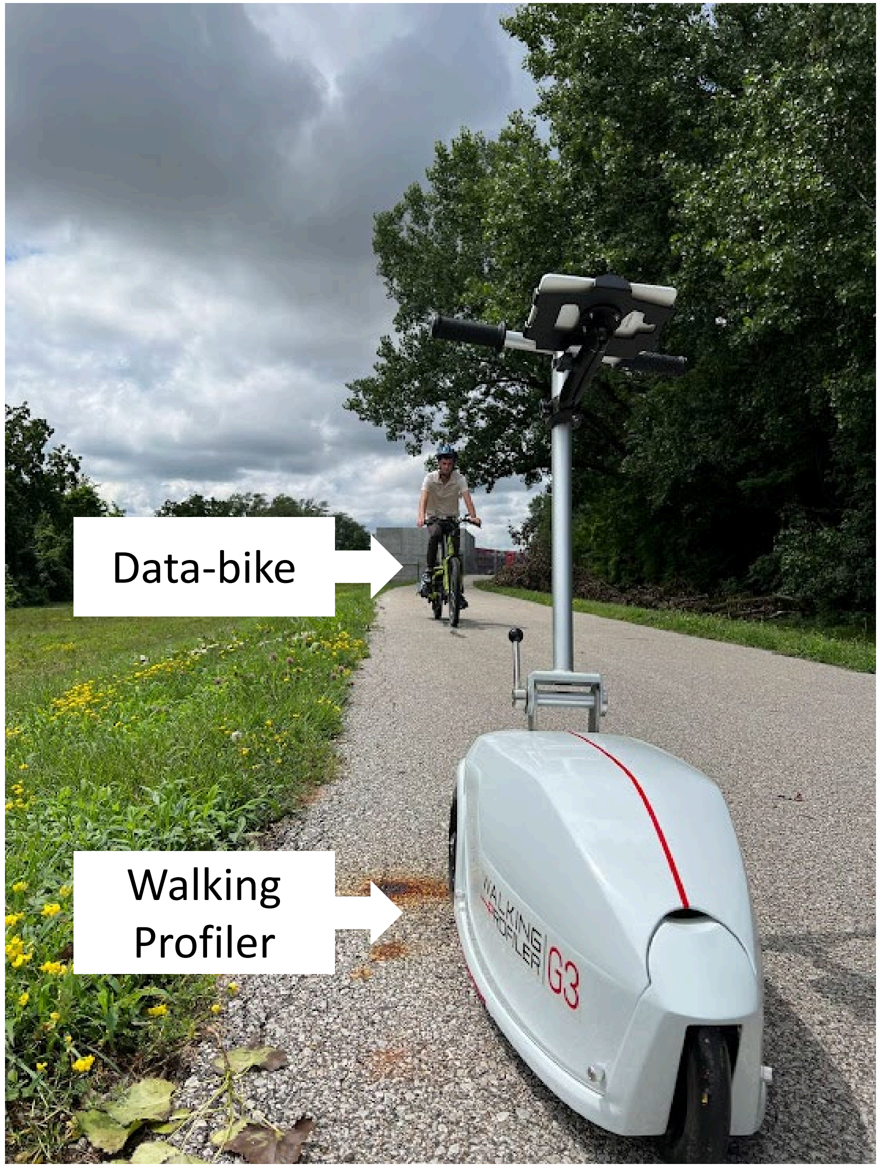
Location of the sites on the map



Sites were marked with an unique ID

Control Sites Data Collection

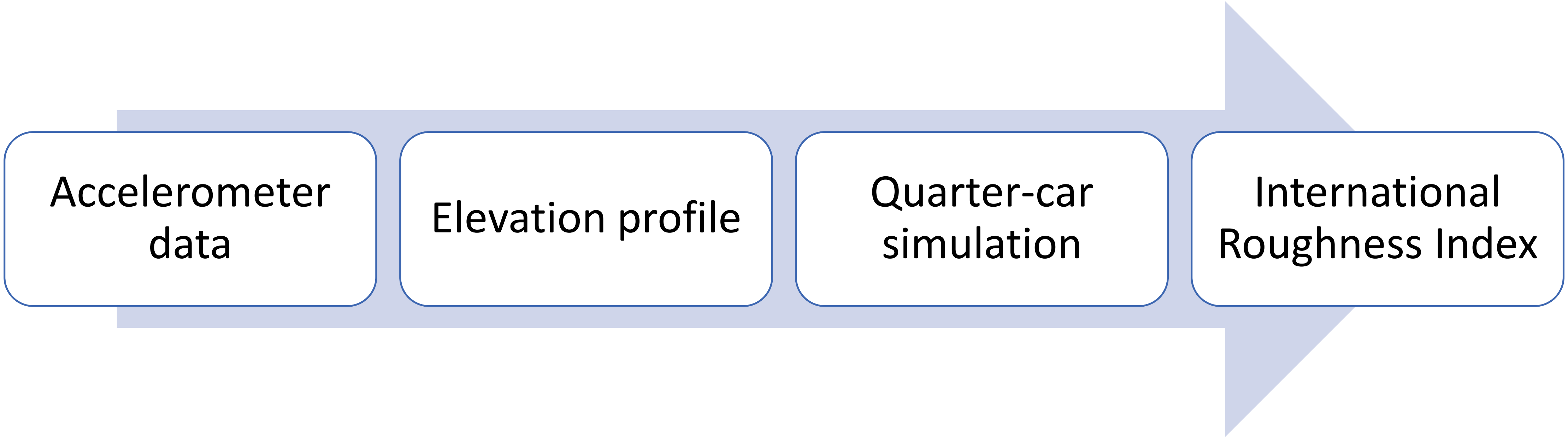
- Both Walking profiler and Data-bike
- Data collected at right lane path
  - 04 Runs per segment (2 runs in each direction)
- Walking Profiler
  - Walking speed- 1.8 mph
  - 3 runs per segment
- Control sites were collected in 2022 & 2023.



Development of a Roughness Index for Pedestrian Infrastructures

Background

- International Roughness Index (IRI) is a widely accepted measure of pavement condition.
- Surface roughness in terms of user experience while driving on the road.
- Measures suspension movement over some longitudinal distance (in./mile).



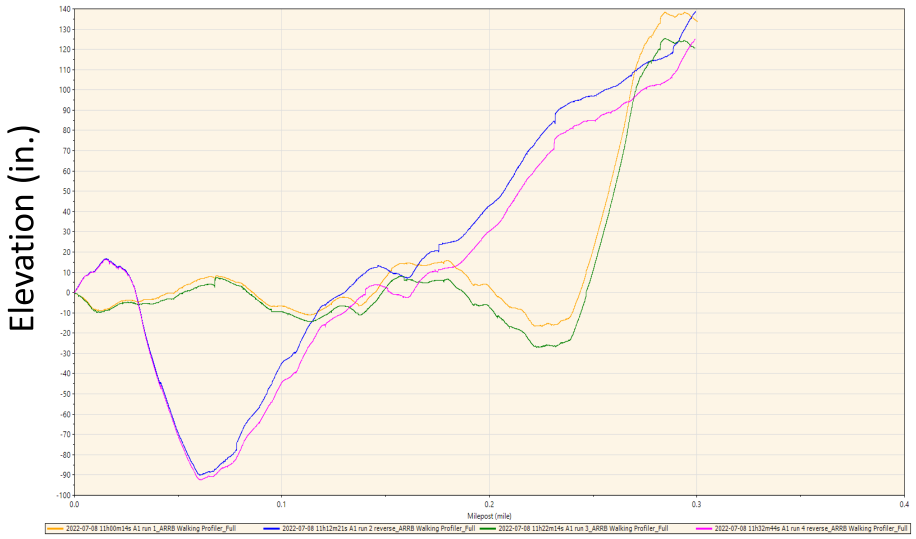
Objective

- To employ and calibrate a bicycle-based algorithm for quantifying surface roughness.
- To verify the roughness measurements from data-bike with a reference system.

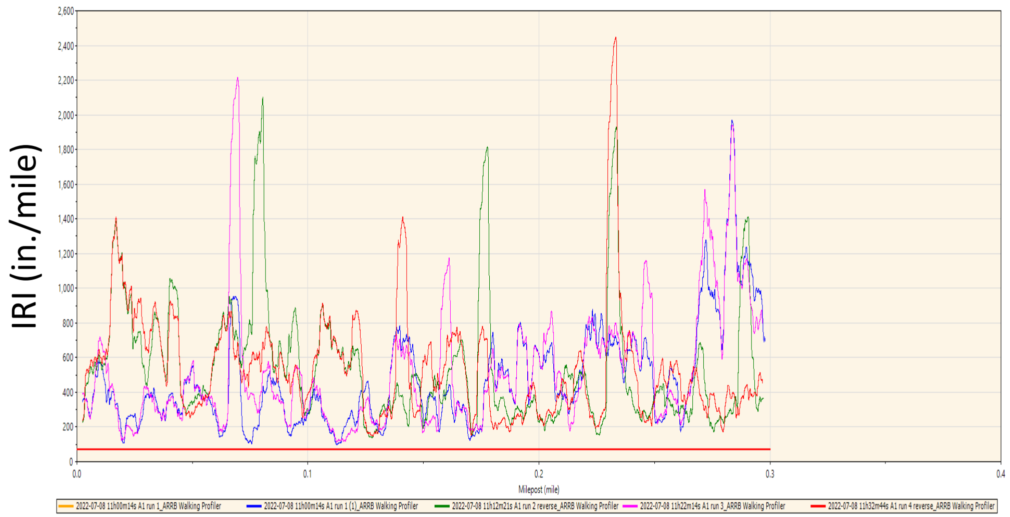
Walking Profiler-based IRI

ProVAL software
(recommended by manufacturer)

Raw Elevation Profile



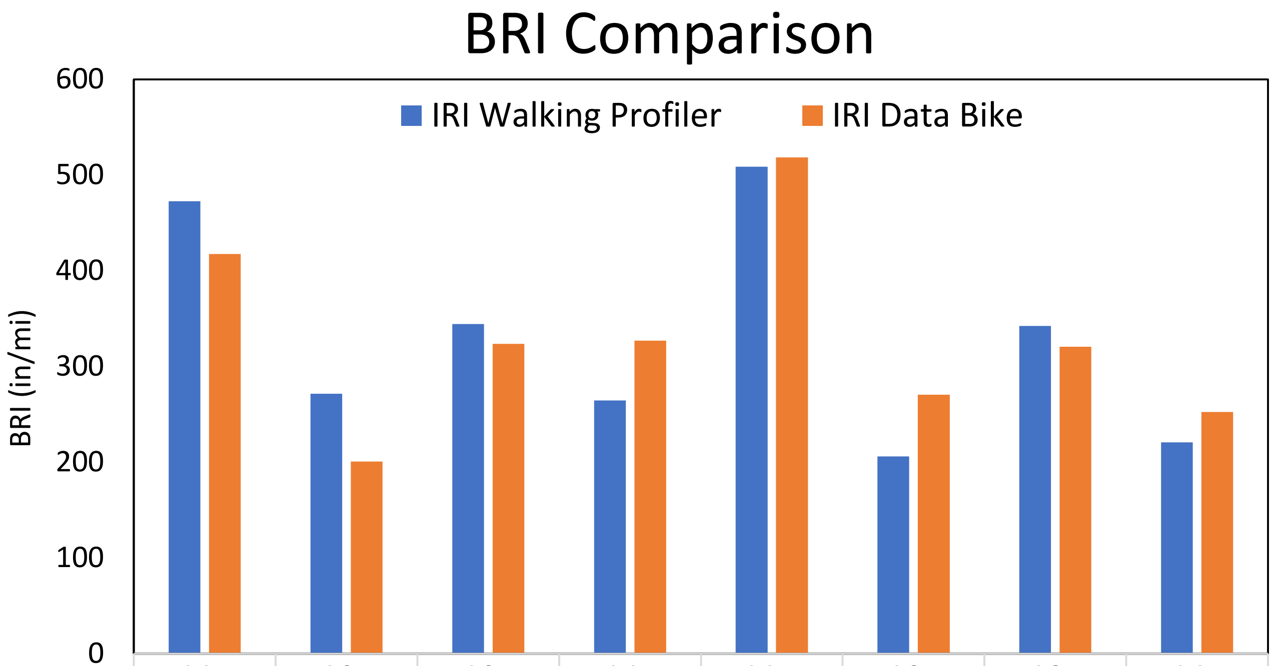
Estimated IRI



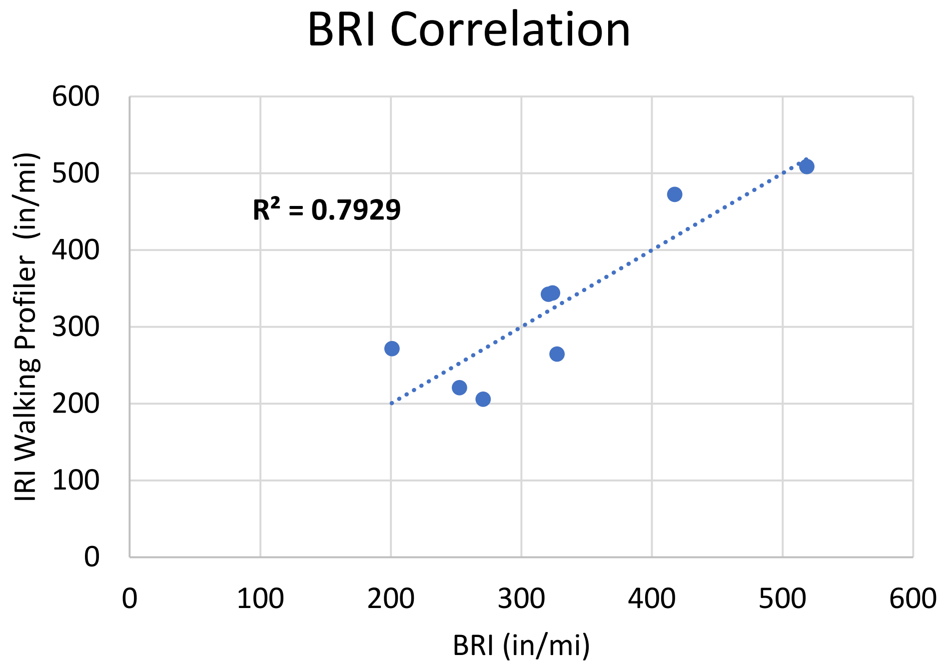
- Longitudinal elevation profile for 4 runs
  - ✓ 2 forward runs
  - ✓ 2 reverse runs

- Continuous IRI measurements
  - ✓ Overall IRI – 0.3-mile segment
  - ✓ Fixed interval IRI (specified interval)

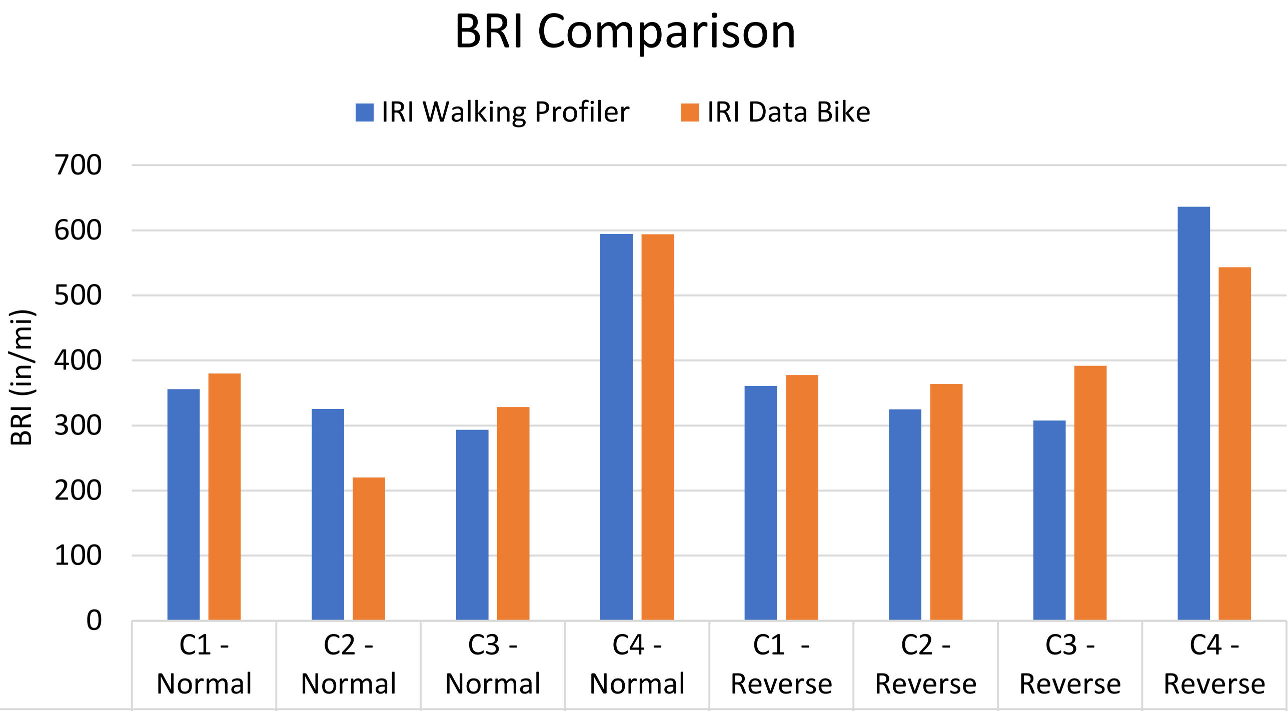
Results: AC Trail



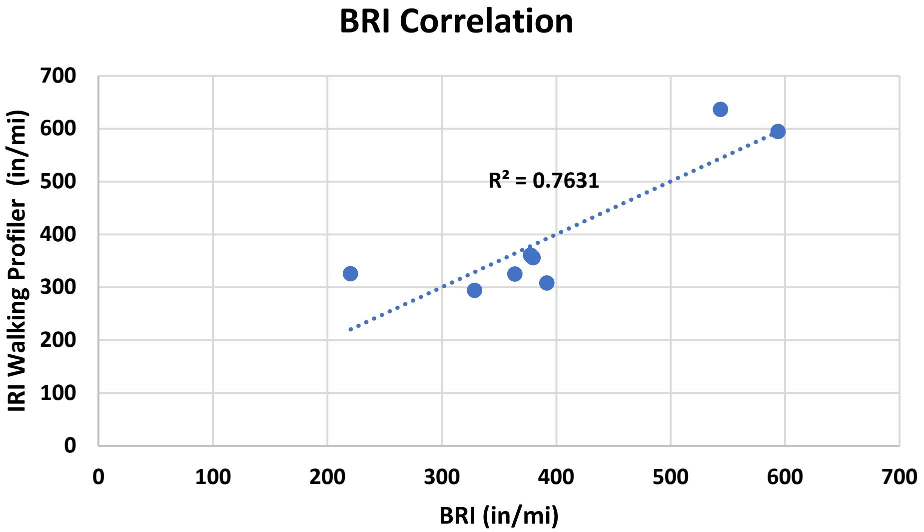
	A1 - Normal	A2 - Normal	A3 - Normal	A4 - Normal	A1 - Reverse	A2 - Reverse	A3 - Reverse	A4 - Reverse
IRI Walking Profiler	472.7341	271.5899	344.3268	264.4911	508.8125	206.0069	342.4078	220.779
IRI Data Bike	417.41	200.72	323.75	327.12	518.47	270.5	320.63	252.55



Results: PCC trail

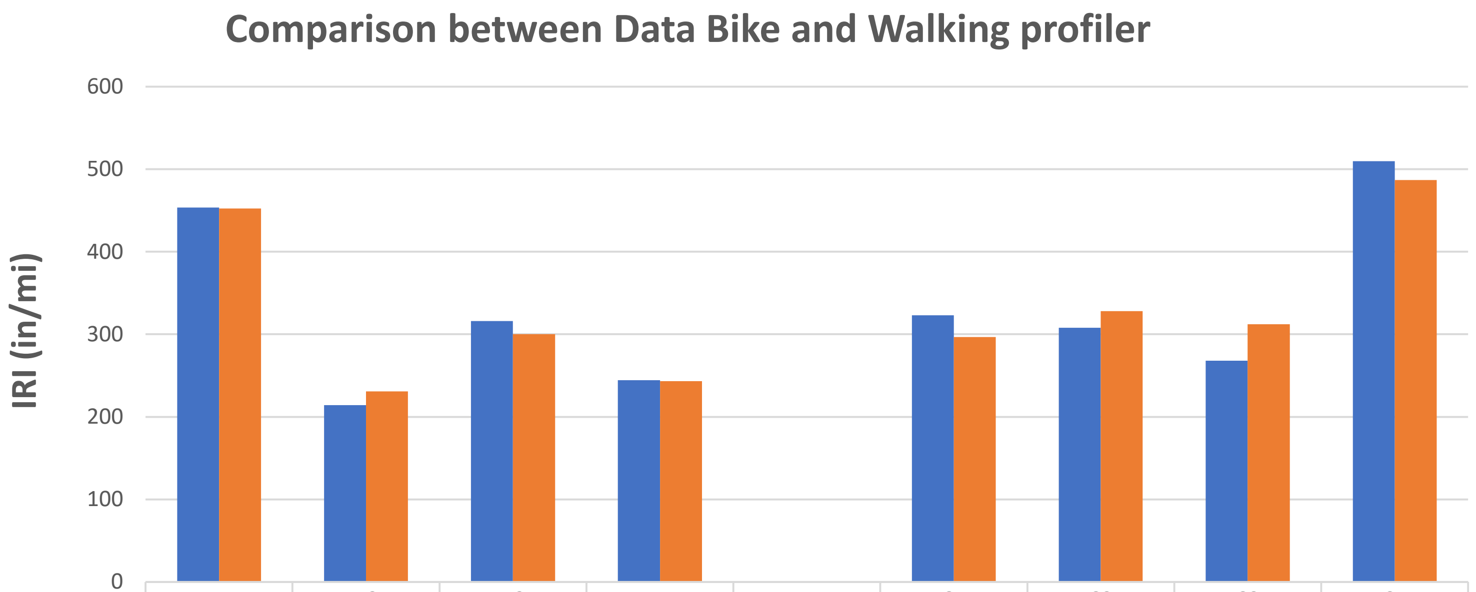


	C1 - Normal	C2 - Normal	C3 - Normal	C4 - Normal	C1 - Reverse	C2 - Reverse	C3 - Reverse	C4 - Reverse
IRI Walking Profiler	355.871175	325.562738	293.516663	594.6207	360.738313	324.871575	307.668931	636.1353
IRI Data Bike	379.83	220.22	328.55	593.73	377.61	363.92	391.71	543.41



Control Sites 2023

- Satisfactory agreement with the reference profiler.

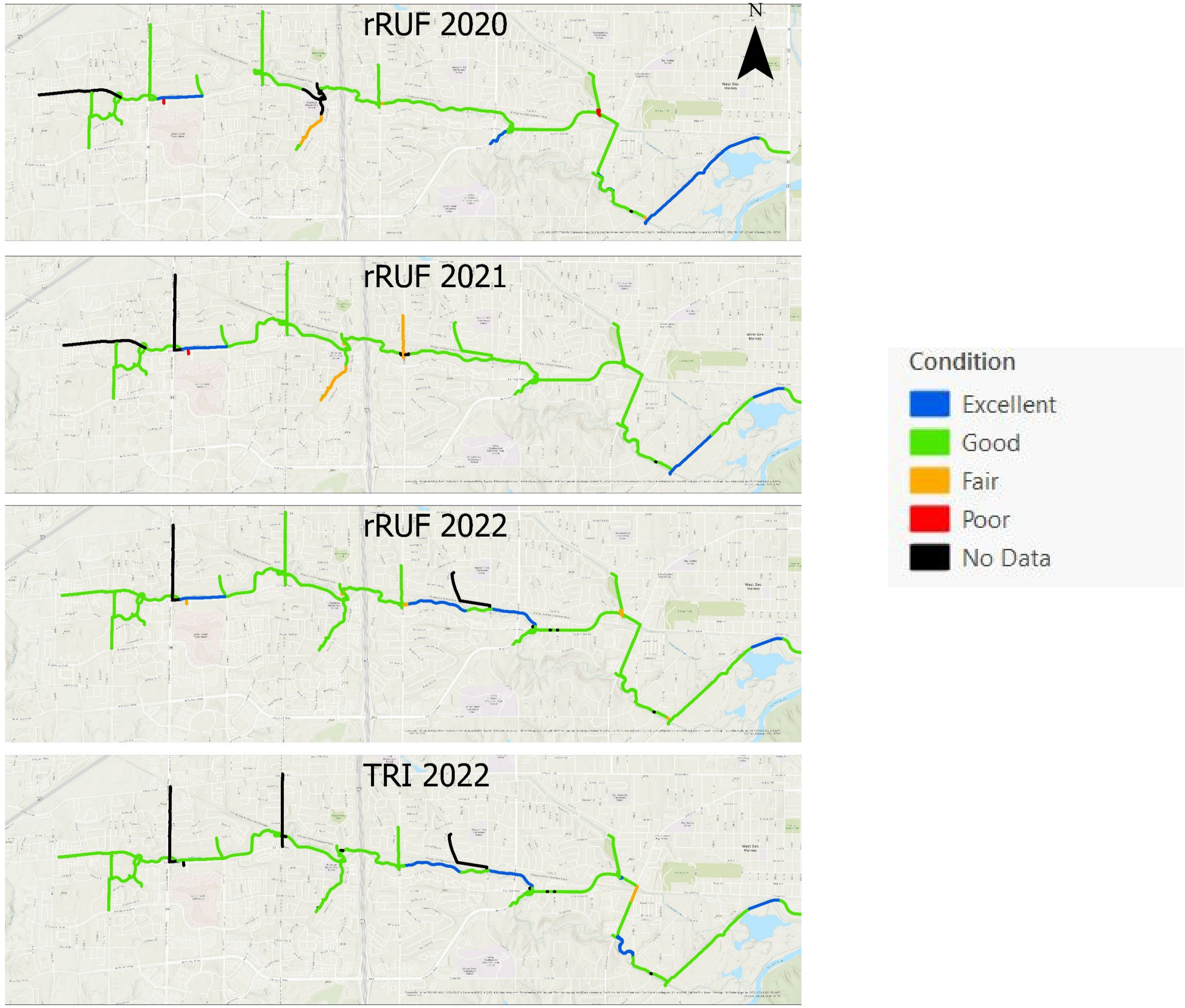


	A1	A2	A3	A4		C1	C2	C3	C4
Walking profiler IRI	453.5670667	214.2789	316.0262333	244.3871667		322.9281667	307.993	268.0324333	509.6135667
Data Bike IRI	452.2246886	230.9897076	300.166621	243.1174522		296.820739	328.0812837	312.1610417	486.7282213

Segment ID

Network-level Deployment

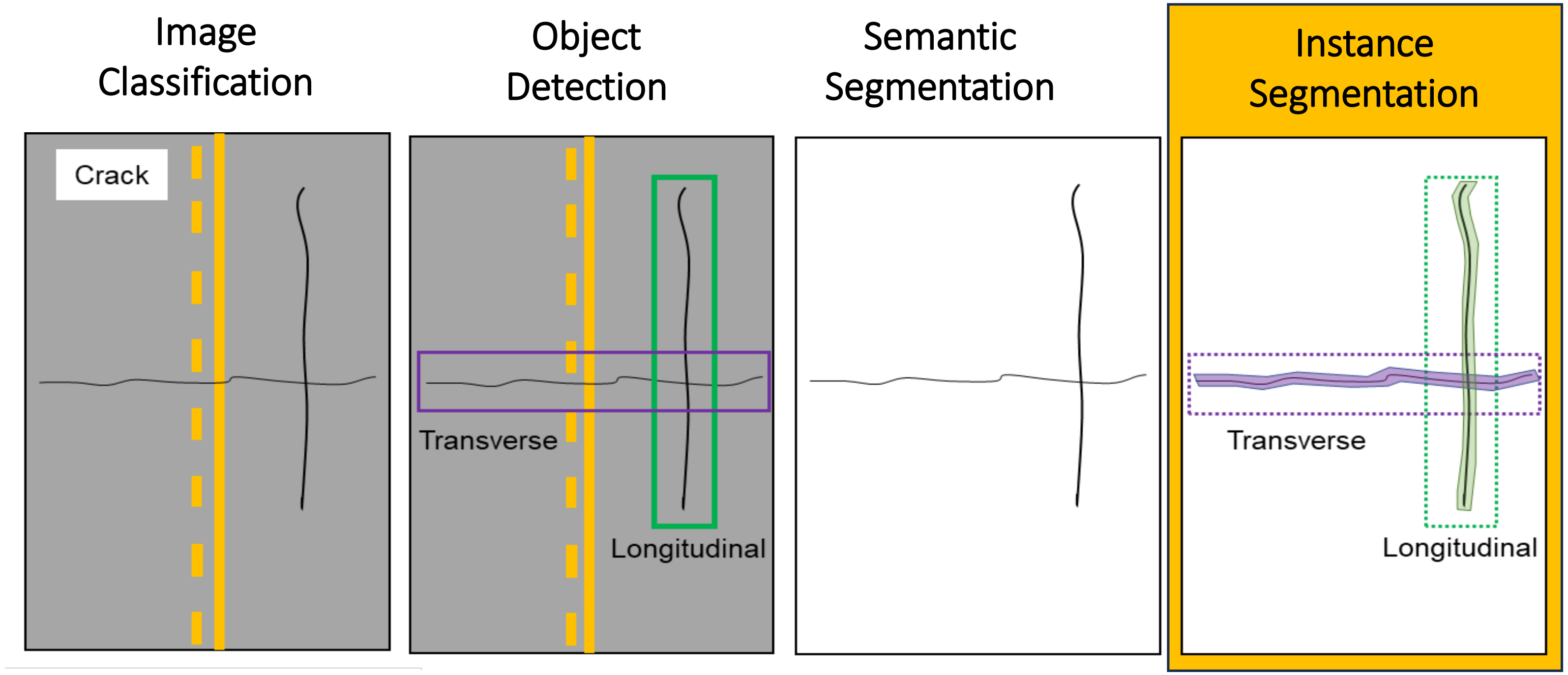
Des Moines Trails Condition 2020 to 2022



Vision-based Trail Condition Assessment

Vision-based Distress Assessment

- Manual Assessment
  - Human-conducted measurement of distress size and extent from pavement images
- Automated Assessment
  - Automated or semi-automated process minimizing human involvement
  - <u>Deep learning-based computer vision tasks</u>

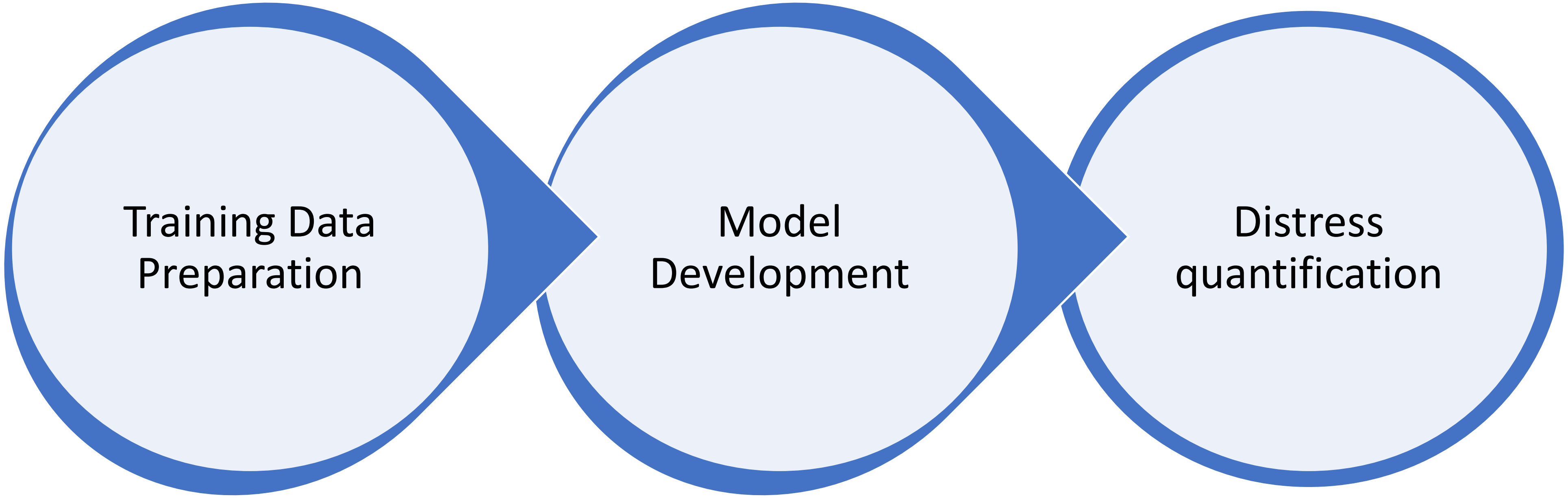


Objective

- Employ state-of-the-art computer vision task to localize, classify, and segment trail distresses.

- Quantify the distresses to allow comprehensive assessment of trail condition

Distress Quantification Workflow



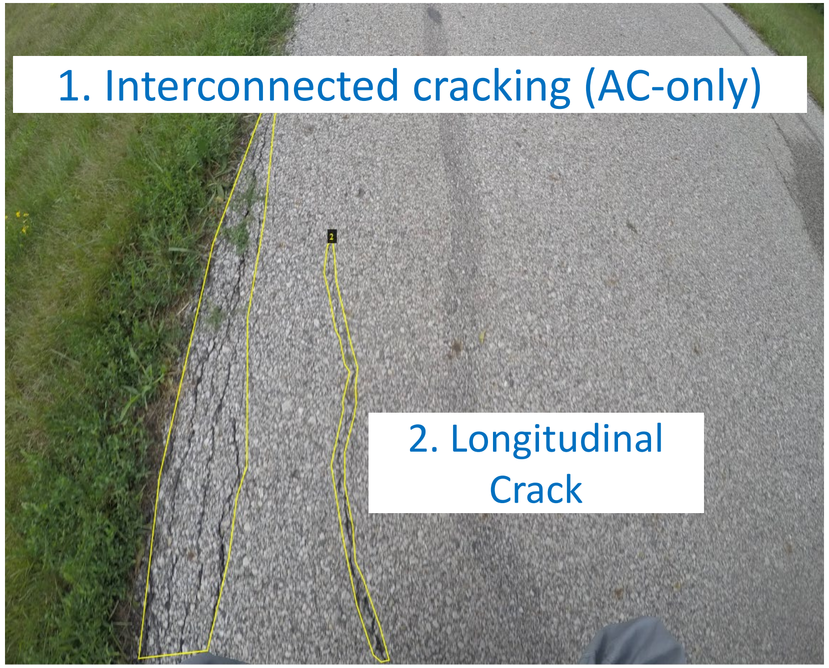
- Step 1: Identify and propose distress types on trails
- Step 2: Annotate the ground truths
- Step 3: Data enhancement

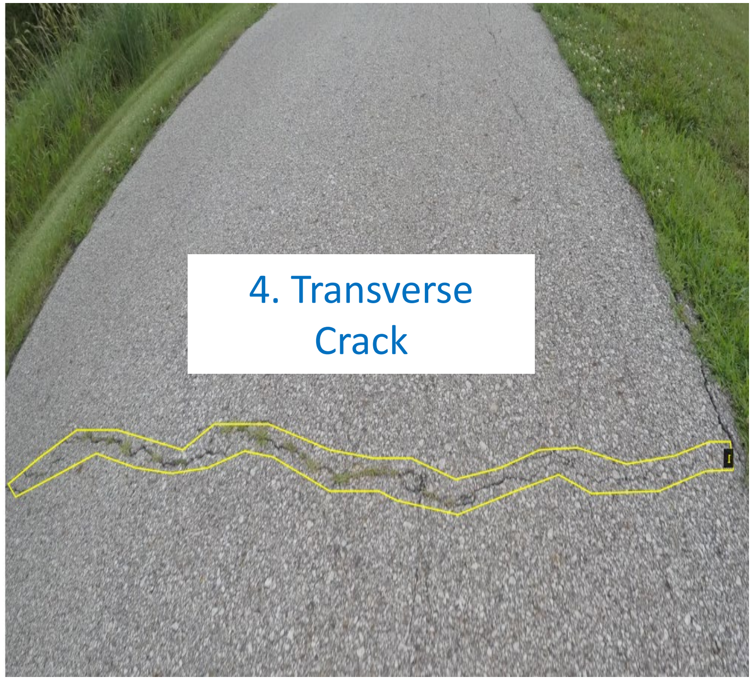
- Step 5: Train the model
- Step 6: Model architecture and hyperparameters tuning
- Step 7: Assess model performance

- Step 8: Filtering predictions
- Step 9: Applying scale model

Proposed Trail Surface Distresses

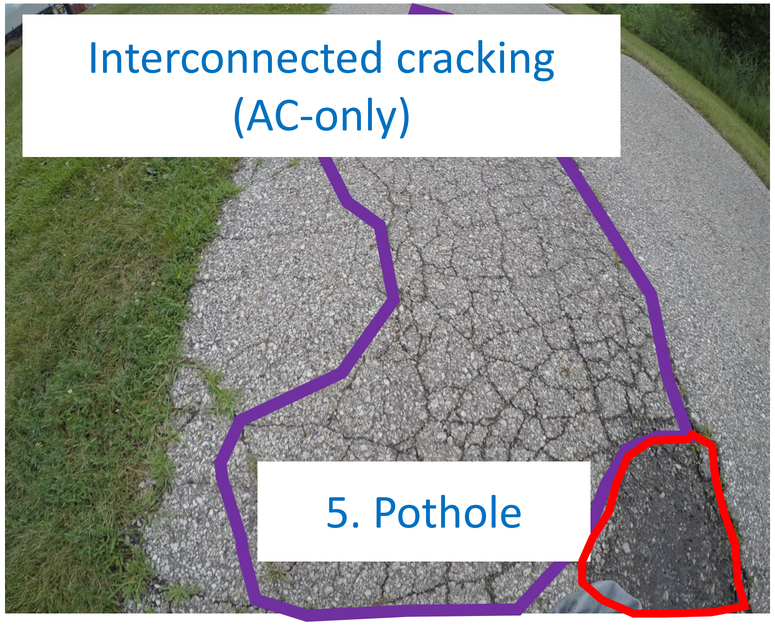
- No standardized guidelines have been found in the literature to classify trail surface distresses.
- Eight (08) distress classes were proposed.

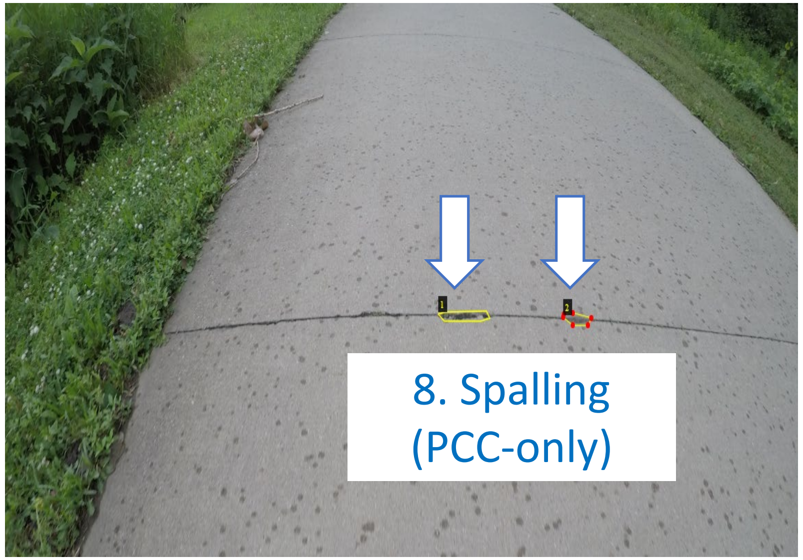




Proposed Trail Surface Distresses

- Some distresses are specific to surface type.





Data preparation

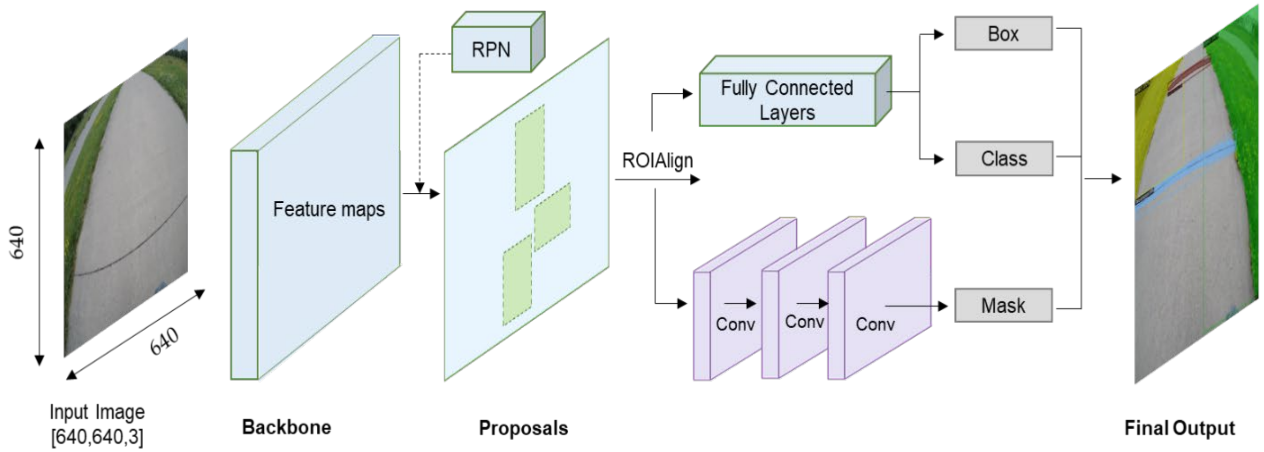
- Annotate with VGG Image Annotator
  - Draw polygon
  - Assign classes to each polygon



Model Training

- Total #images annotated= 4439
  - Training : 70%
  - Validation : 30%

Architecture of Mask R-CNN Model

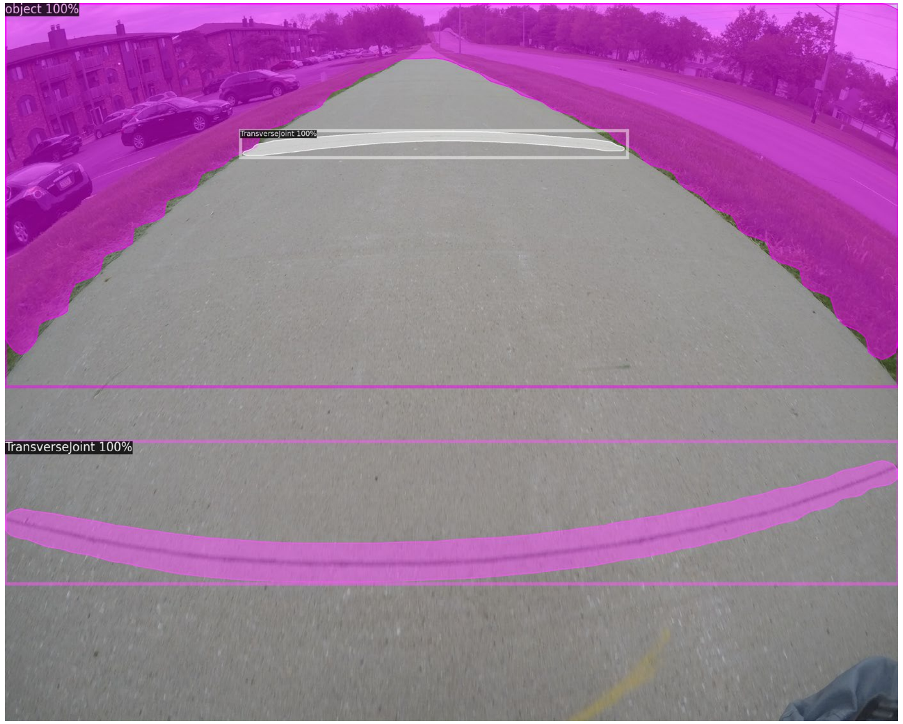


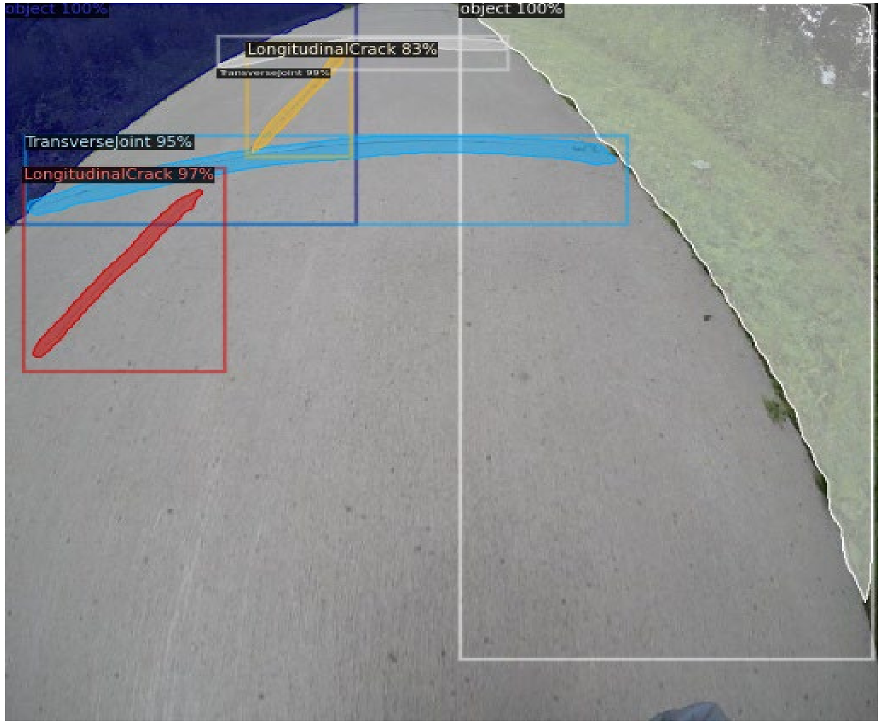
- Model trained for 80,000 iteration to improve the prediction performance.
  - Training time 16 hours.
  - Transfer learning using pre-trained COCO weights.

Model Prediction: PCC

✓Performed robustly on concrete surfaces.

- Transverse Joints (left)
- Longitudinal cracks and Transverse joints (right)

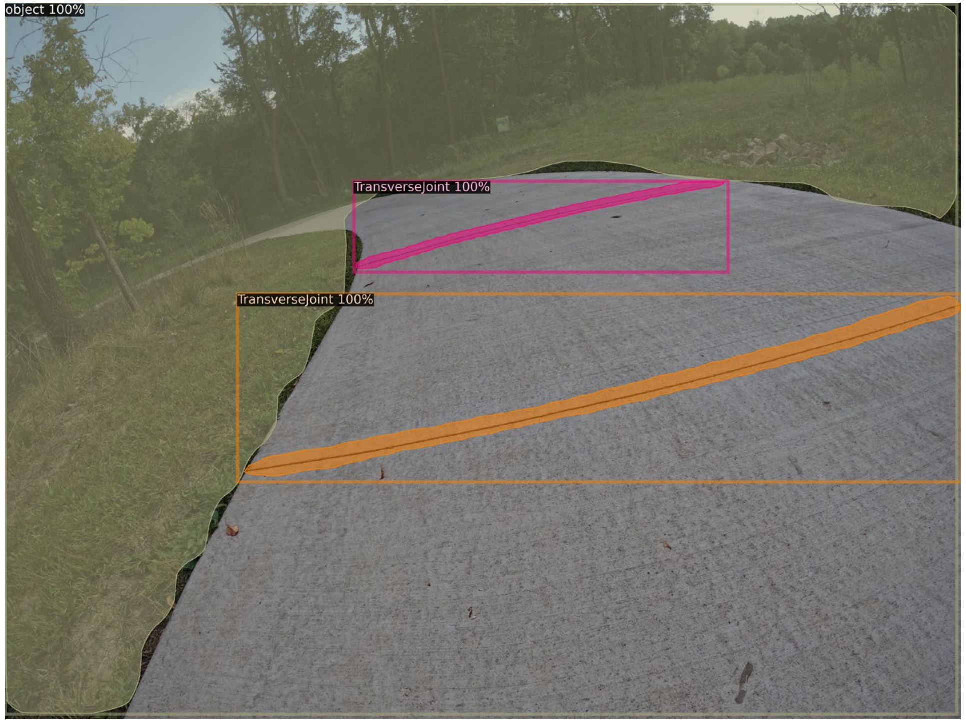


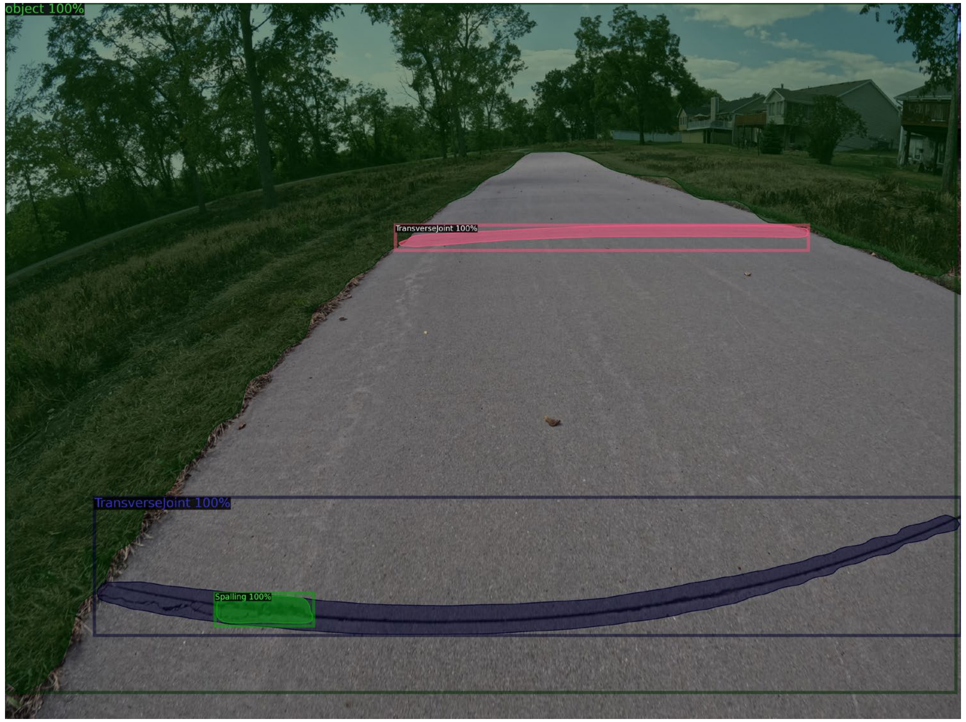


Model Prediction: PCC

✓Performed well on skewed images and even for smaller distresses such as spalling

- Transverse Joints appearing skewed (left)
- Spalling detected (right)

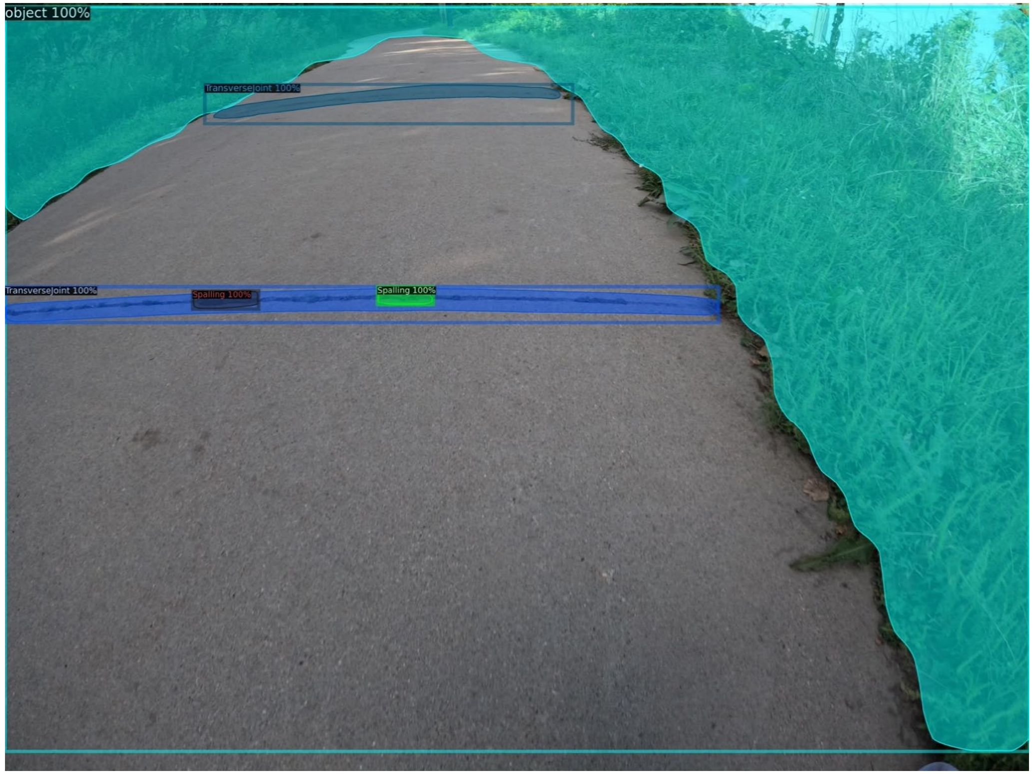




Model Prediction: PCC

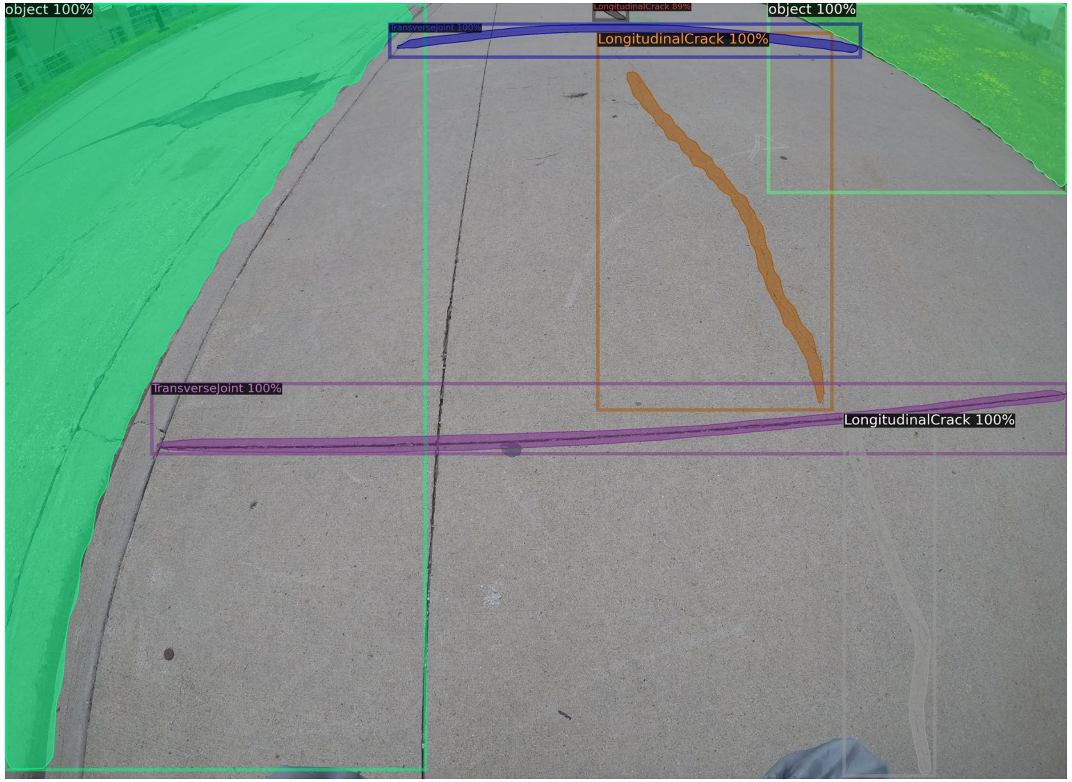
✓Detection performance on shadowed images

- Transverse Joints (left)
- Spalling (right)



Model Prediction: PCC

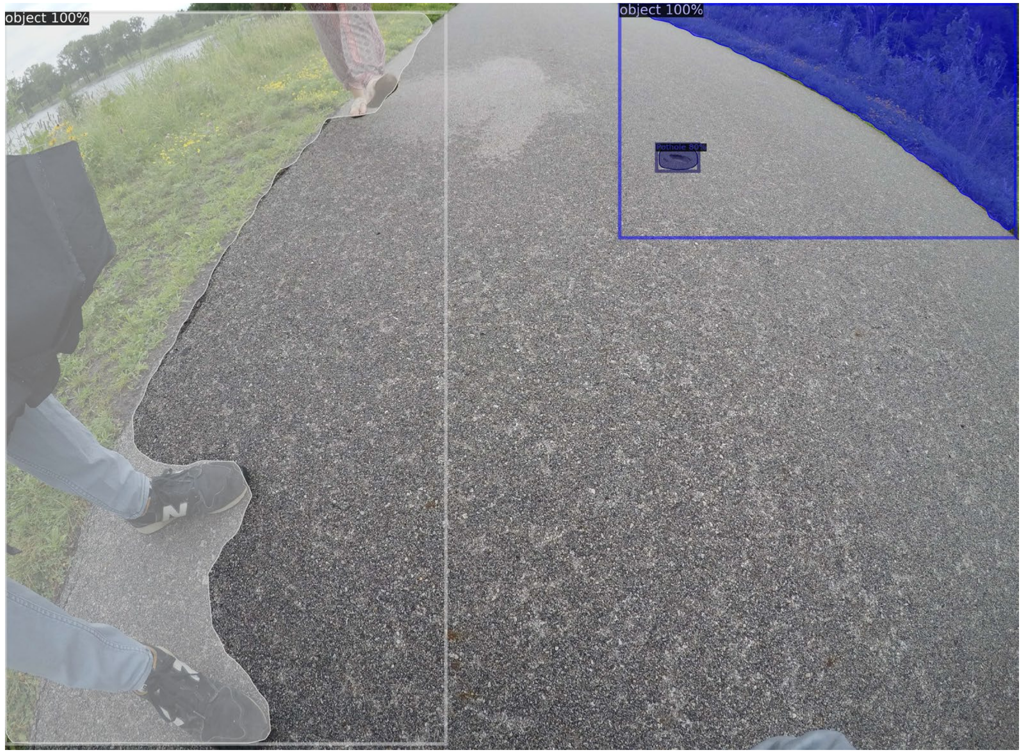
✓ More example of distress identification on PCC surface.

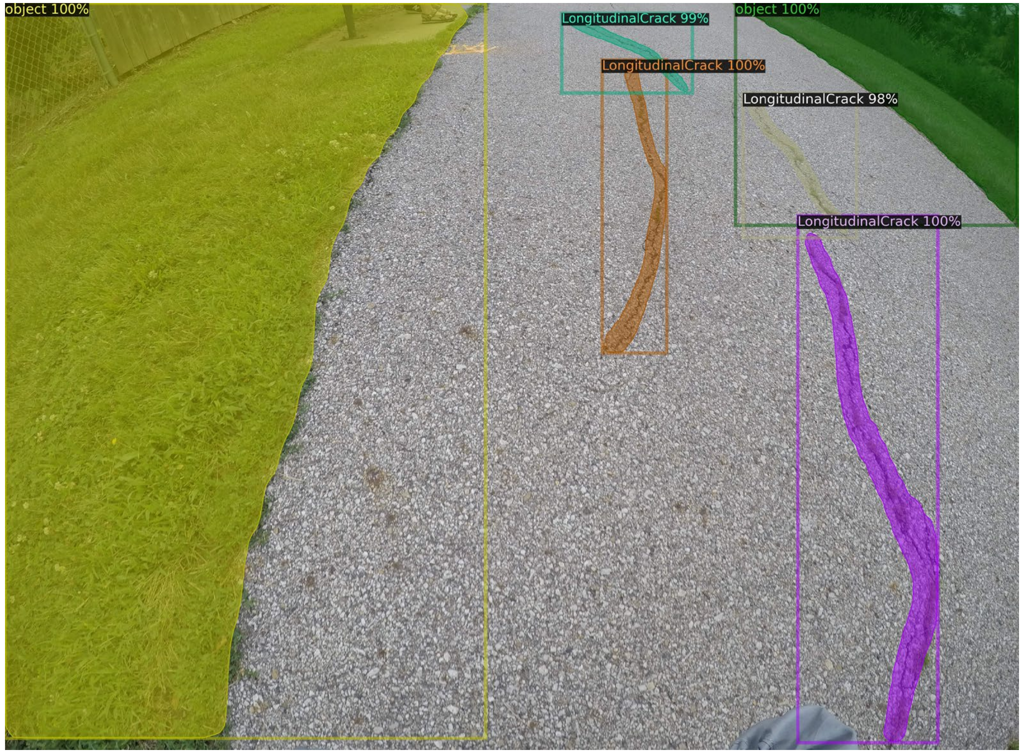


Model Predictions: AC

✓Model performance on AC surface

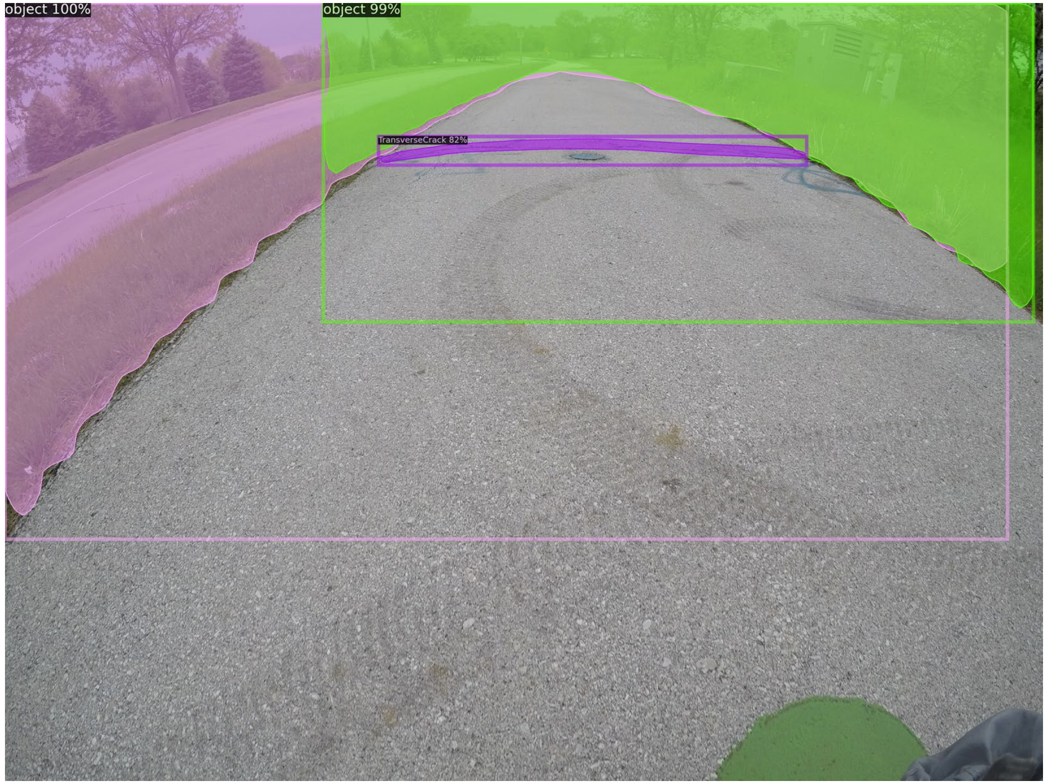
- Pothole (left)
- Multiple longitudinal cracks (right)

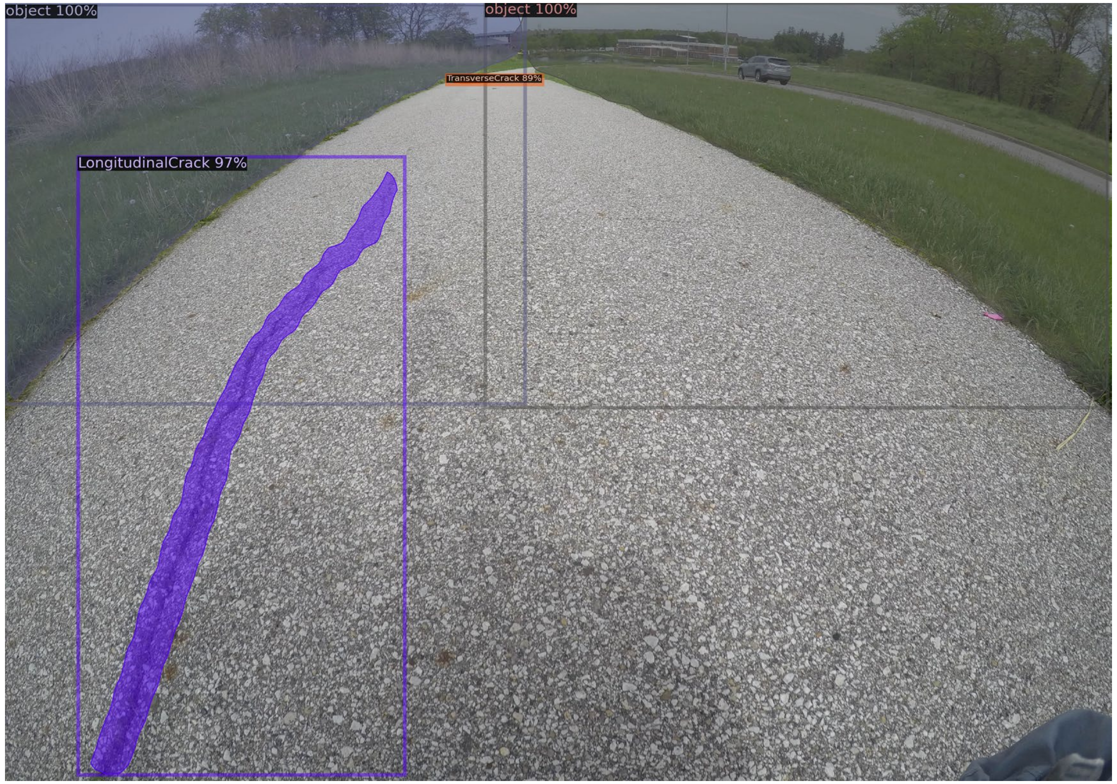




Model Predictions: AC

✓Detection of far located transverse cracks.

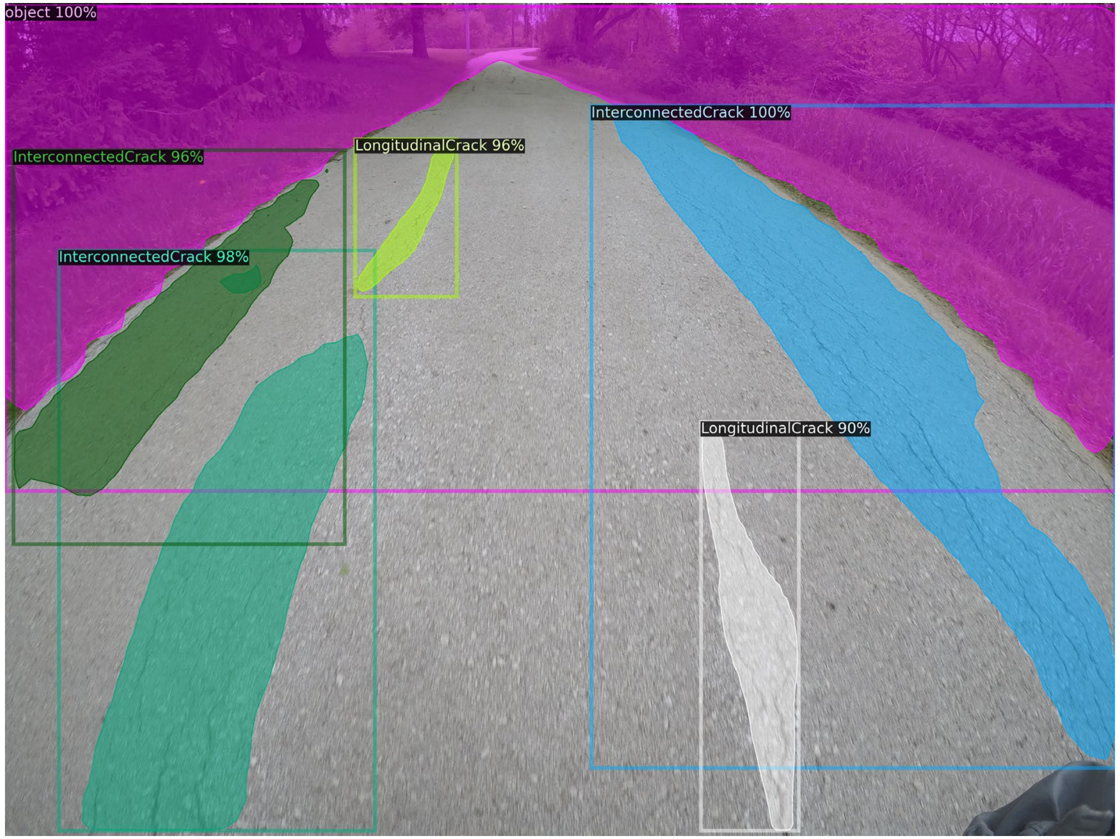


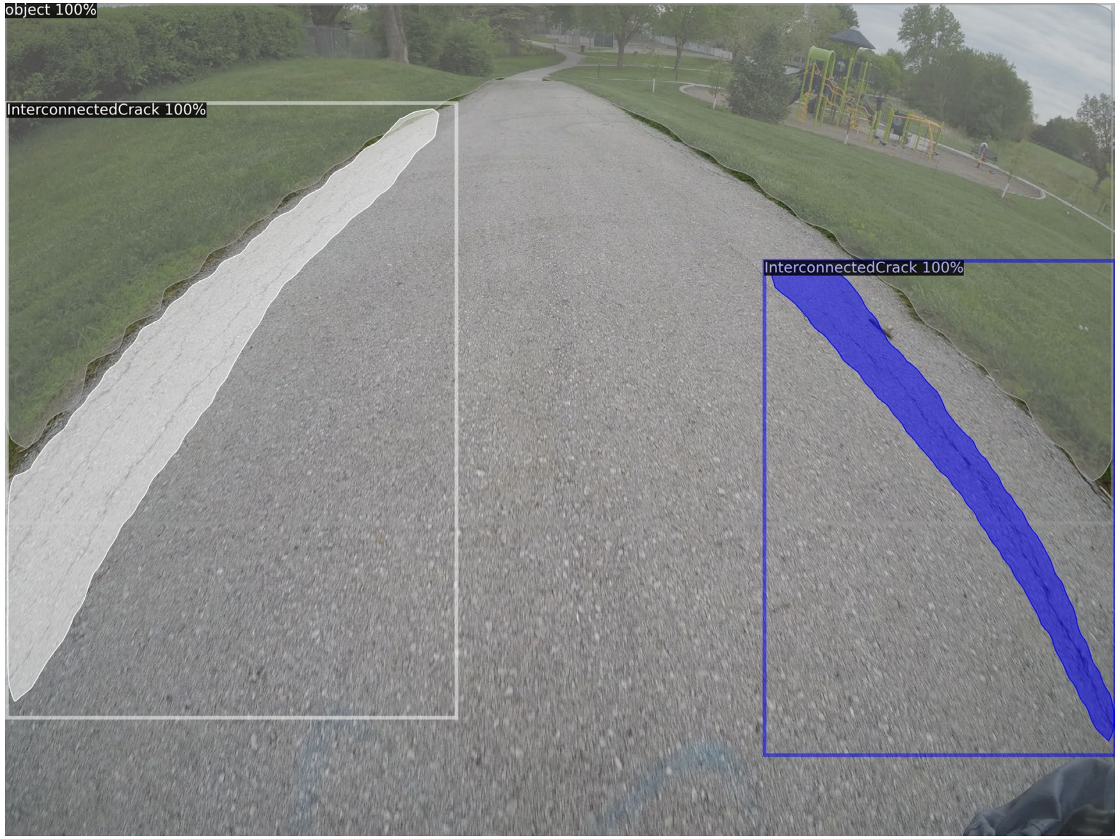


Model Predictions: AC

✓ Good detection capacity on critical distress type-

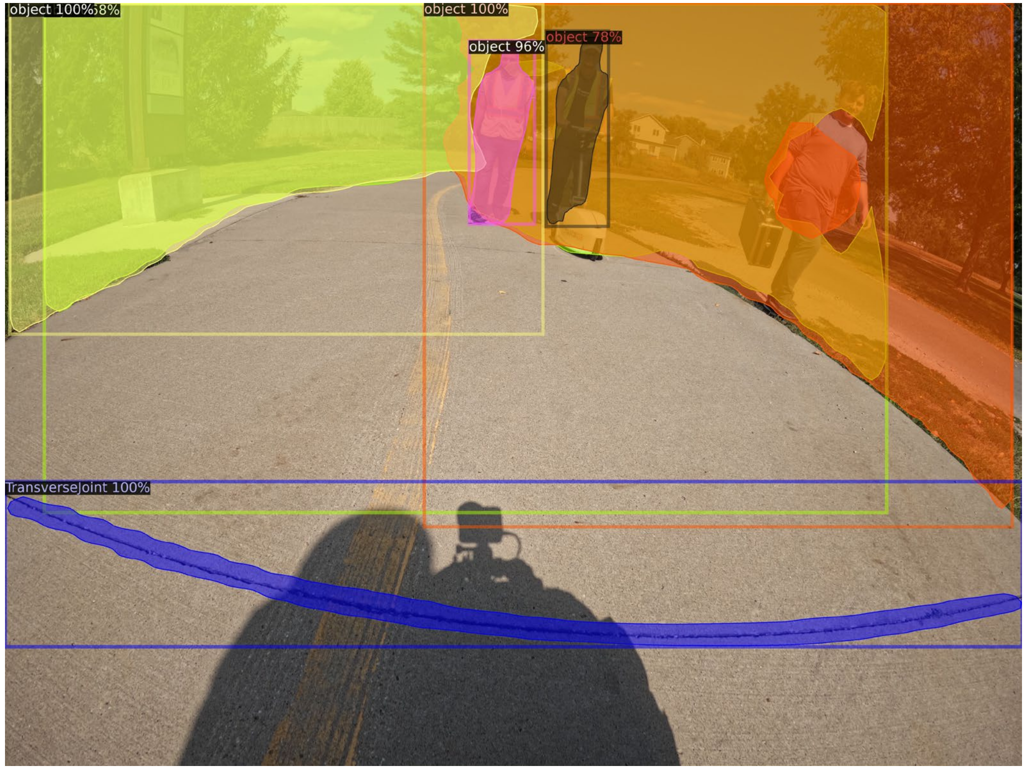
- Interconnected cracks

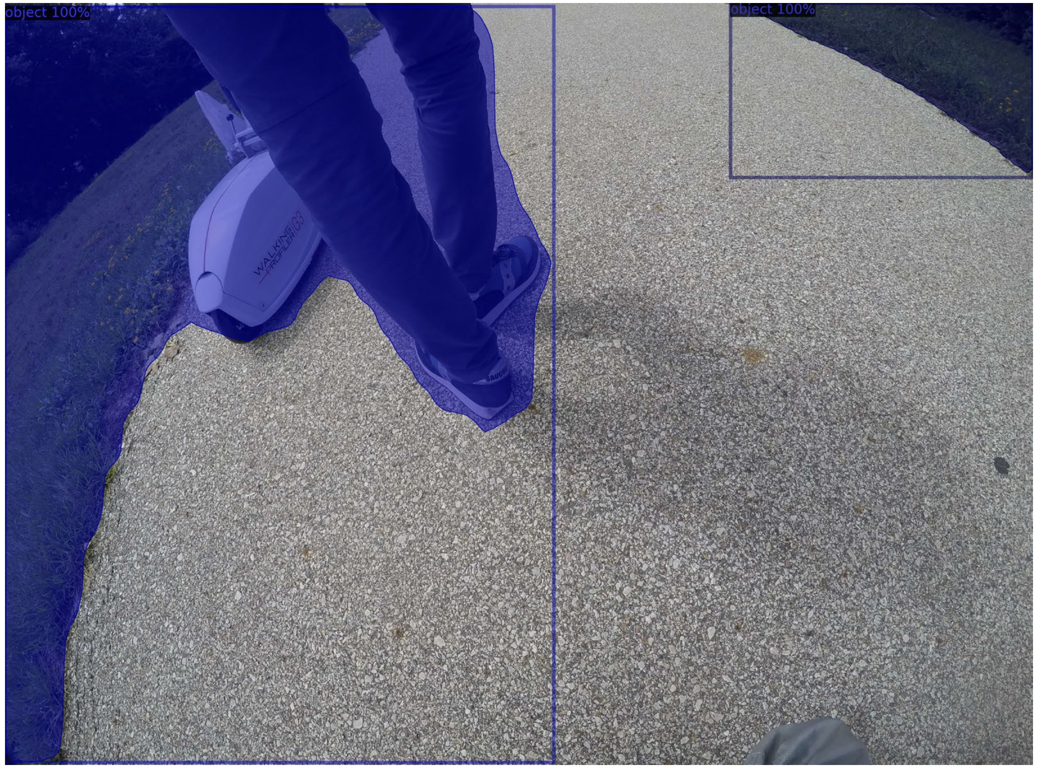




Model Predictions: AC

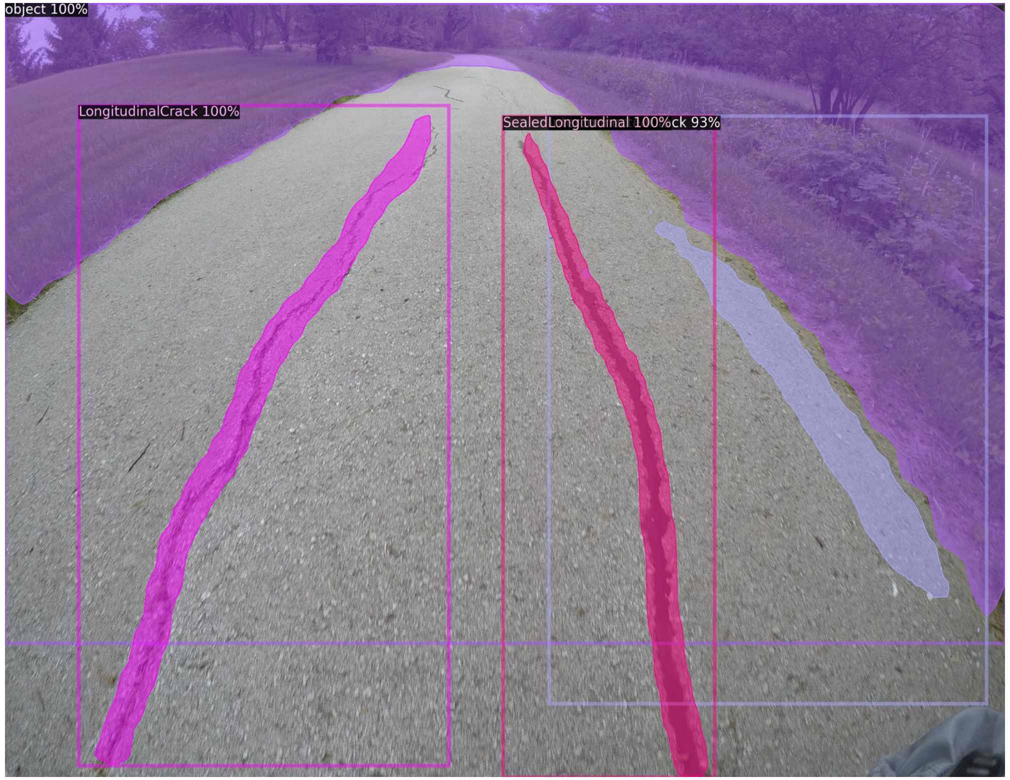
✓Detection performance on trails with pedestrians!

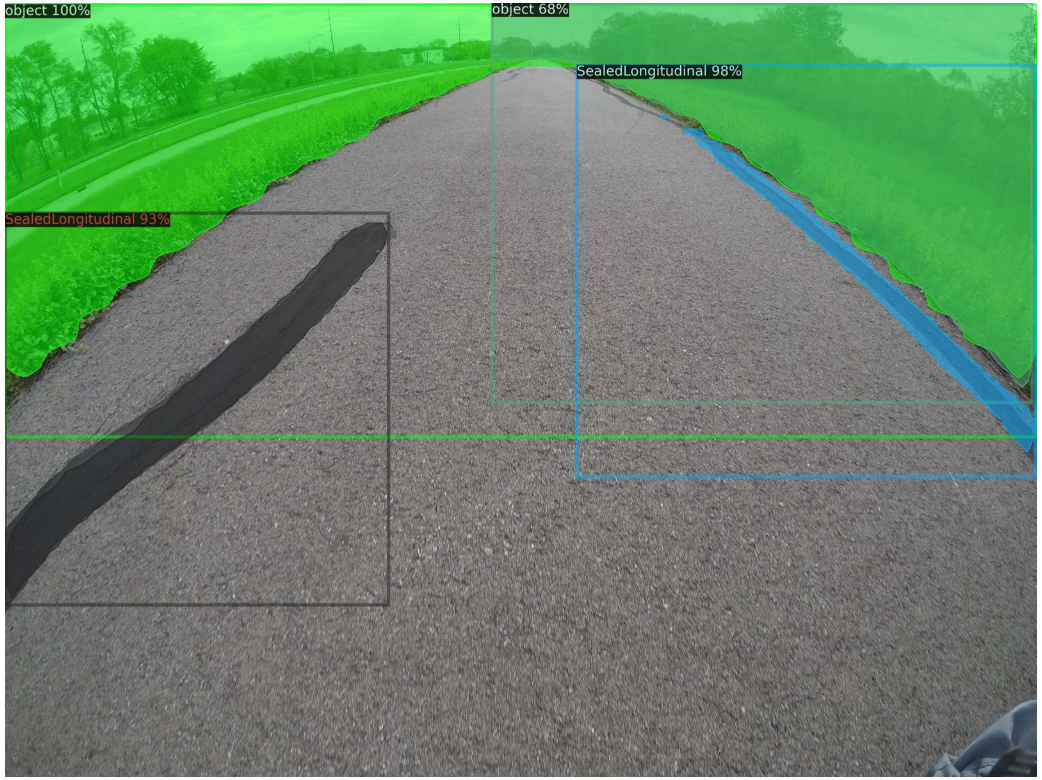




Model Predictions: AC

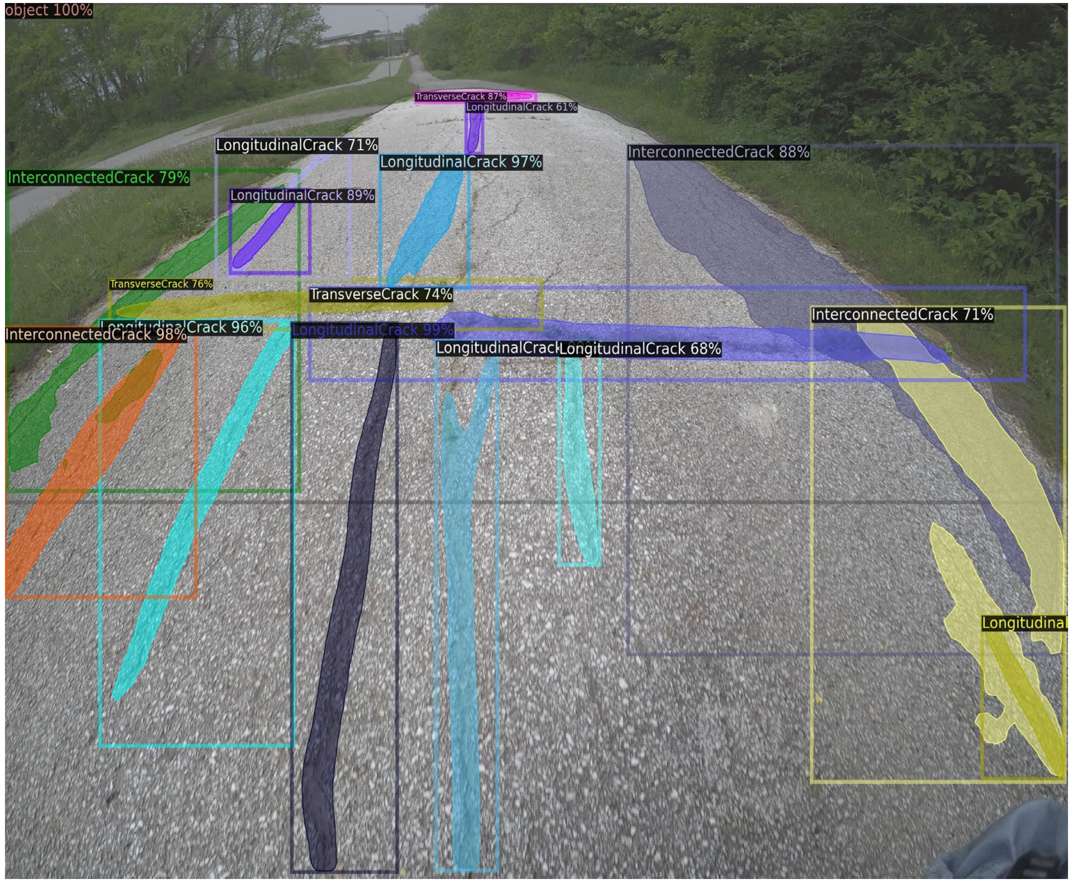
✓Distinguishes the sealed longitudinal cracks that need no maintenance.

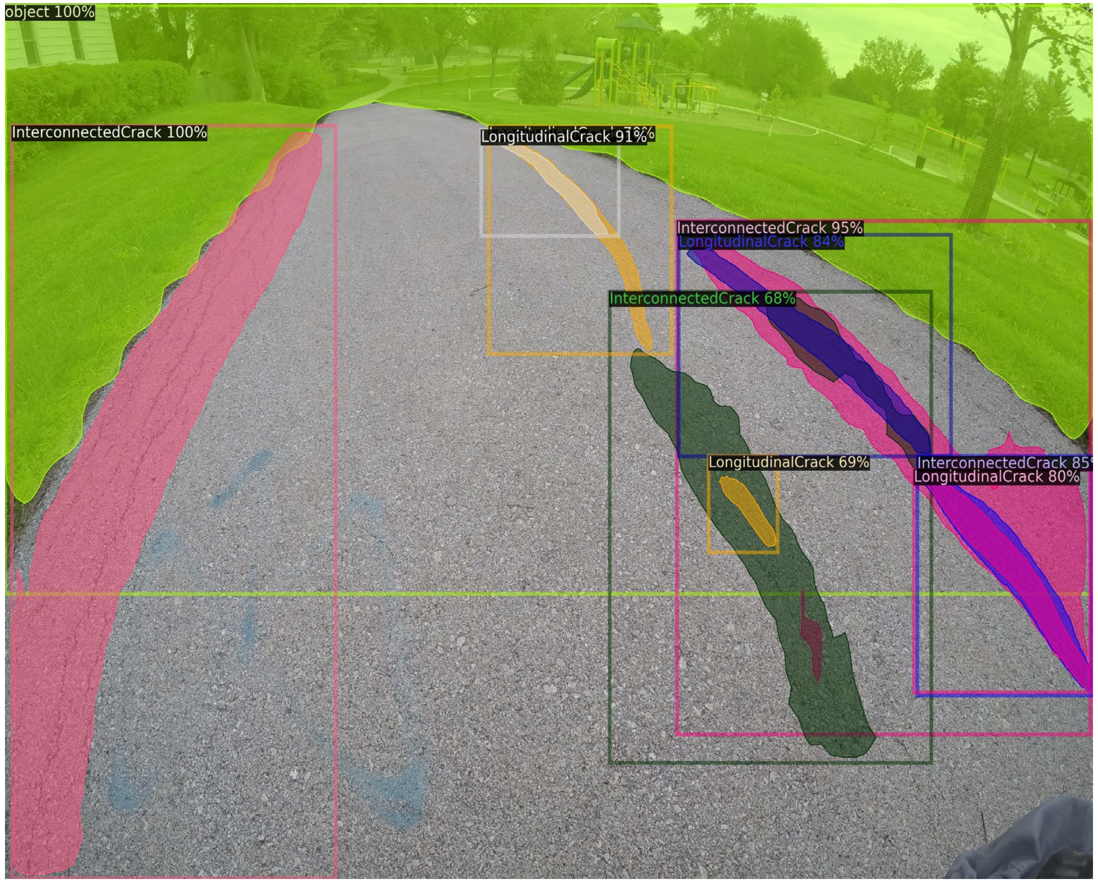




Model Prediction: AC

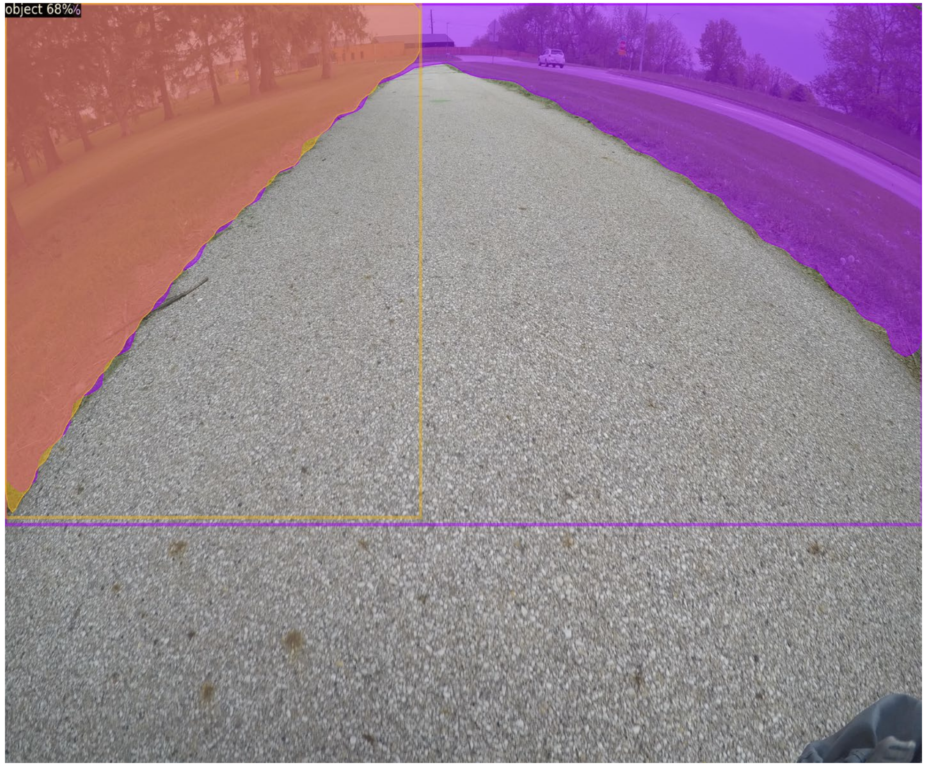
✓Performance on heavily cracked areas.

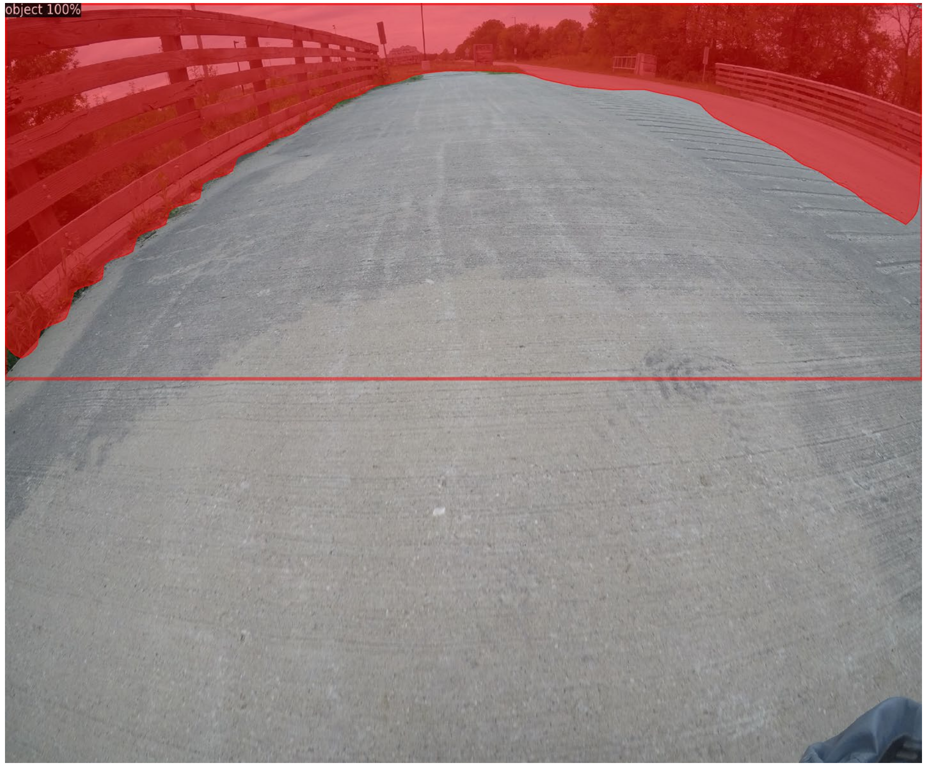




Model Prediction: AC & PCC

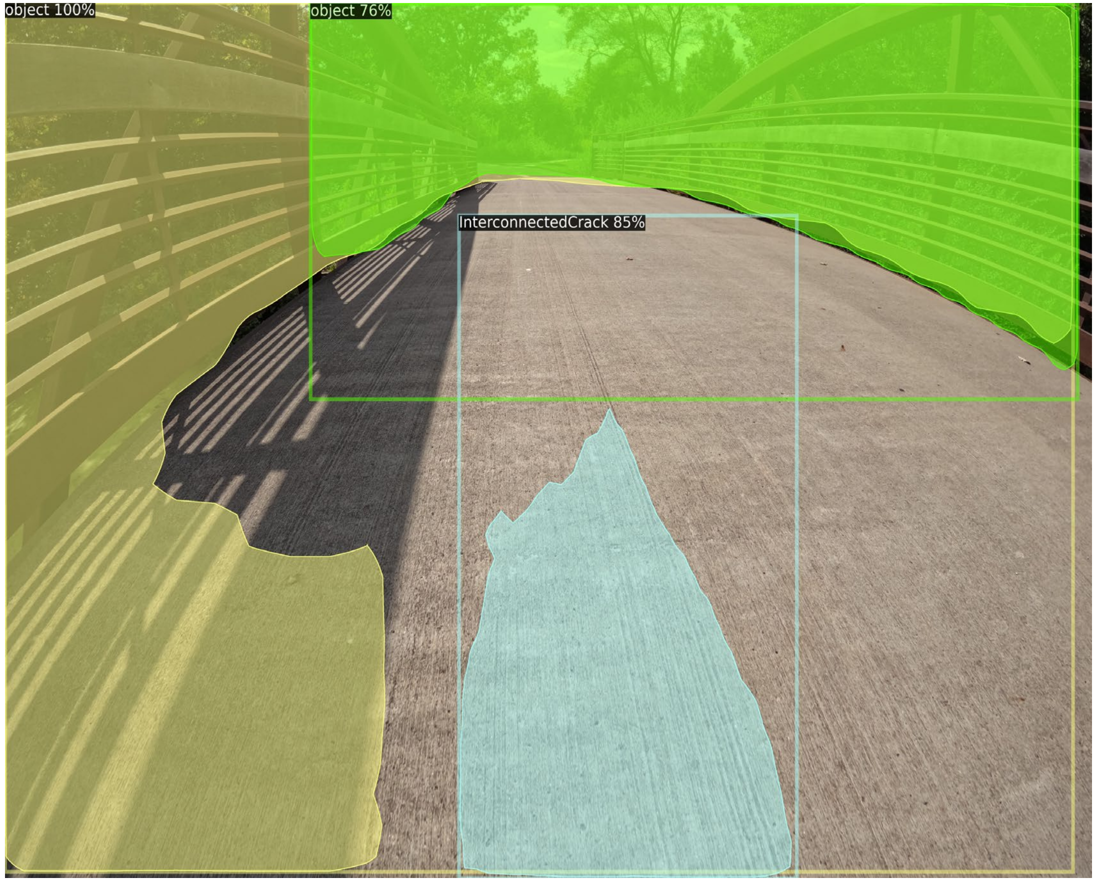
✓ Performance on trails in good condition



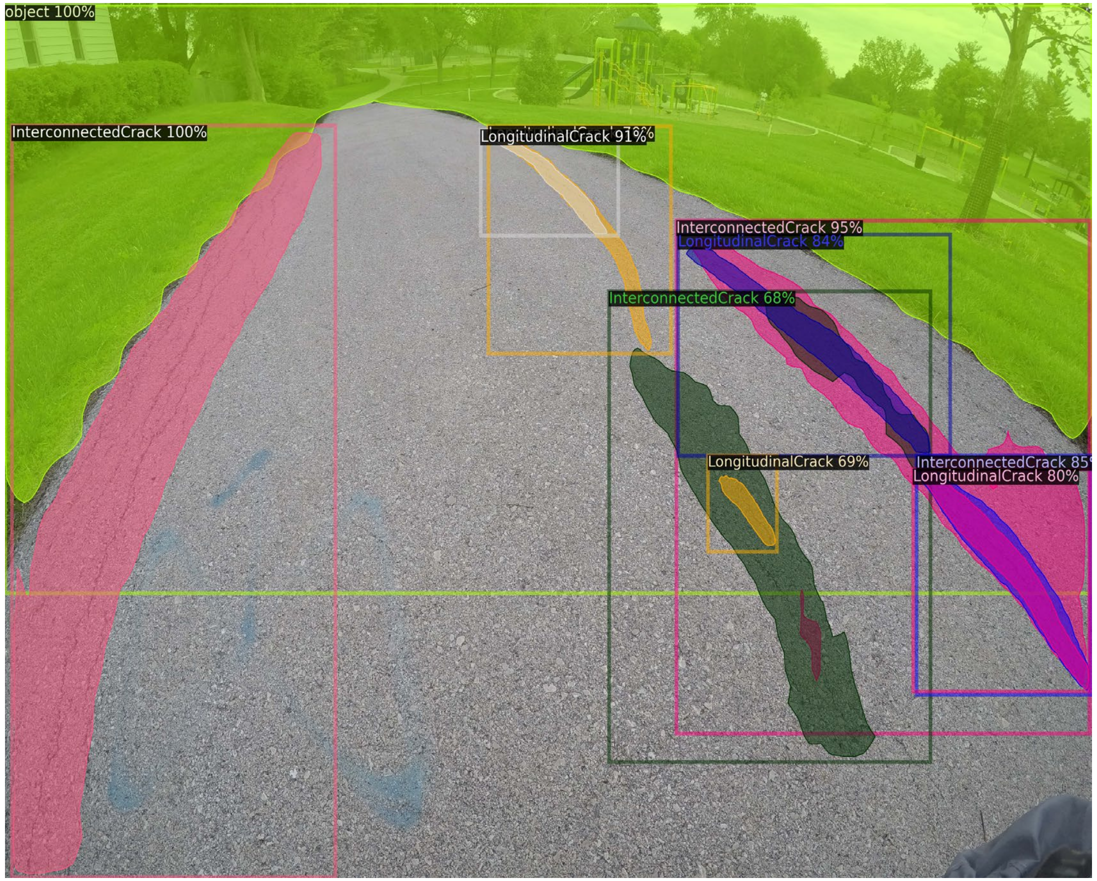


Model Limitations

- Crack-like surface texture caused it to predict Interconnected crack



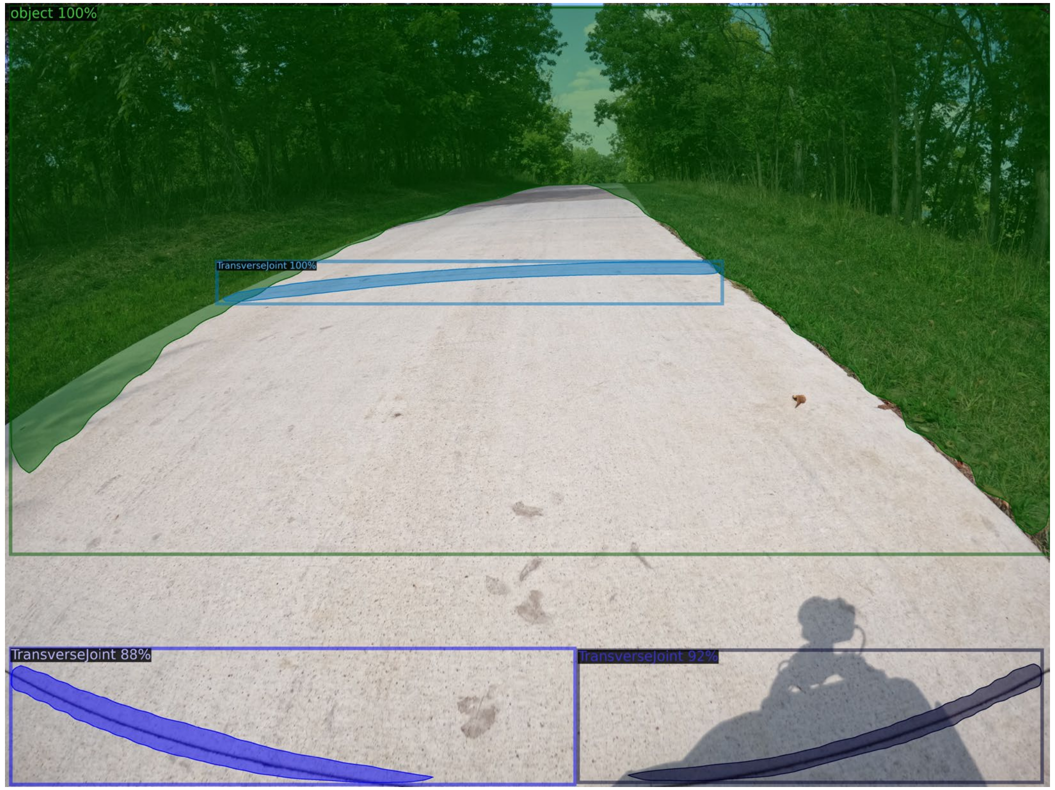
- Overlap of prediction instances



Model Limitations

- Joints far-away not detected

- Two joints detected due to image distortion

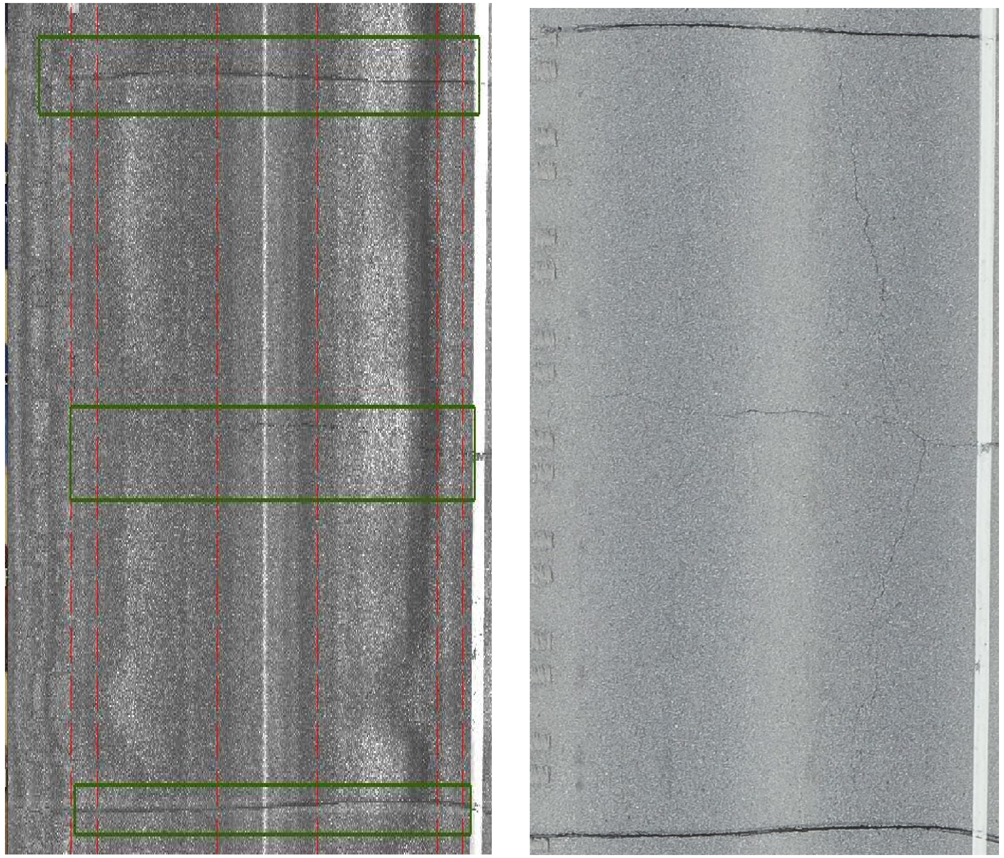


Distress quantification from GoPro Images

Distress quantification

Ideal Scenario

Aerial or Top view images



Go Pro

Wide-angle, Perspective of view

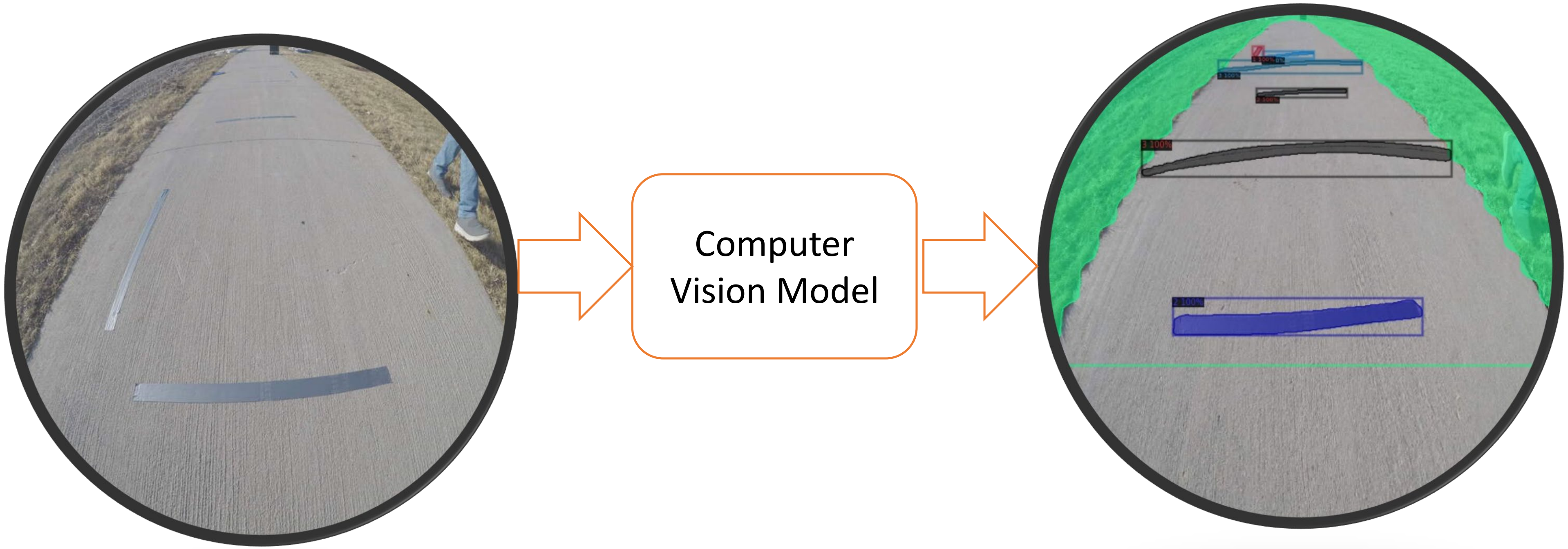
Distress quantification Methodology

- A scale model was developed to account for the distorted nature of GoPro images.
  - Accurately quantifies crack lengths from model’s prediction.

Model’s Predicted Masks → **Scale Model** (• Experimental study • Regression model) → Actual Extent of Distresses

Experimental Study

- ✓Distresses were simulated on field using tapes.
- ✓Model prediction on experimental images



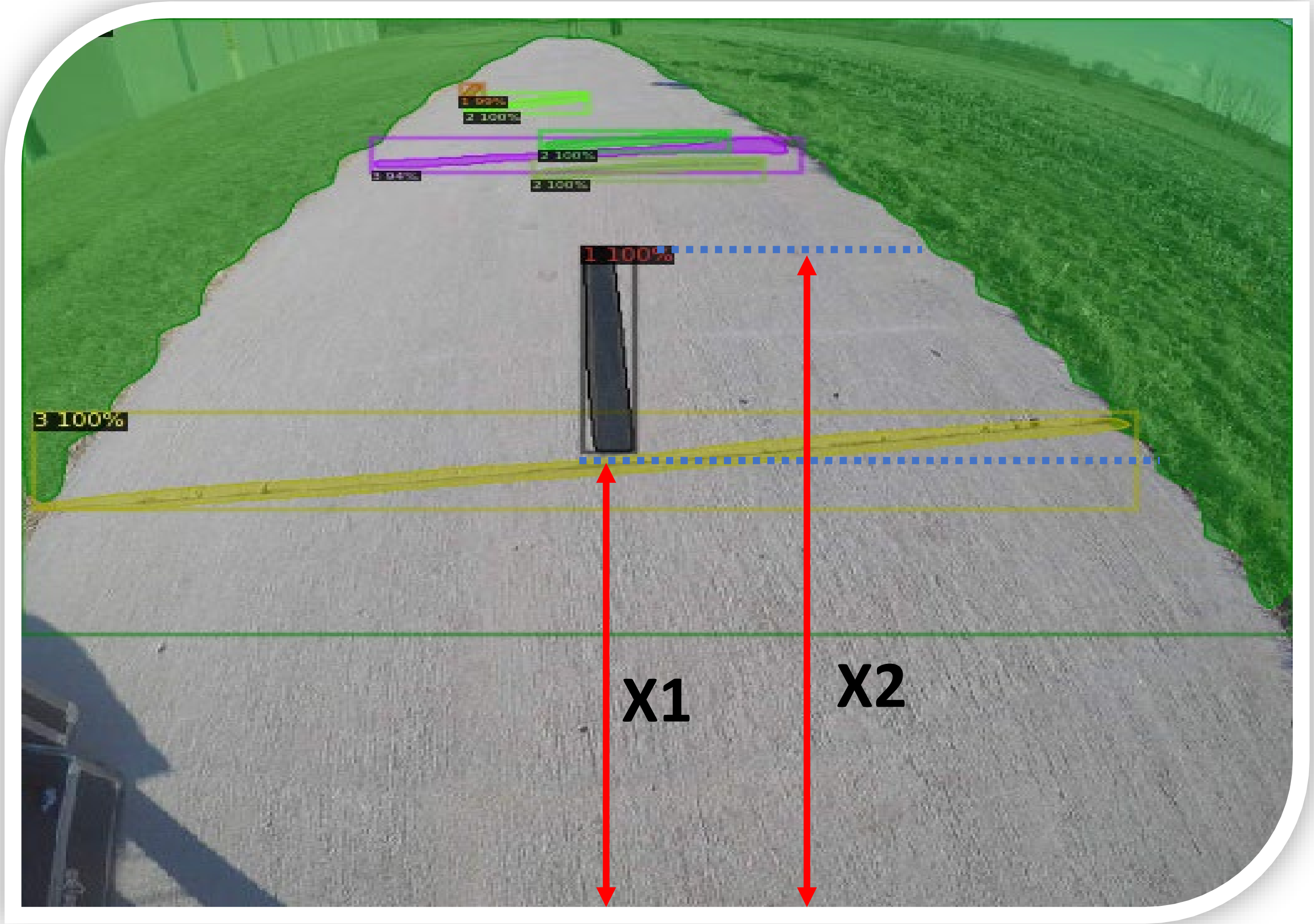
Scale Model Development

- Data Extraction

1. $Distance = X1$

2. $Avg.Distance = \dfrac{X1 + X2}{2}$

3. $Length(px)\ or\ Width\ (px)$



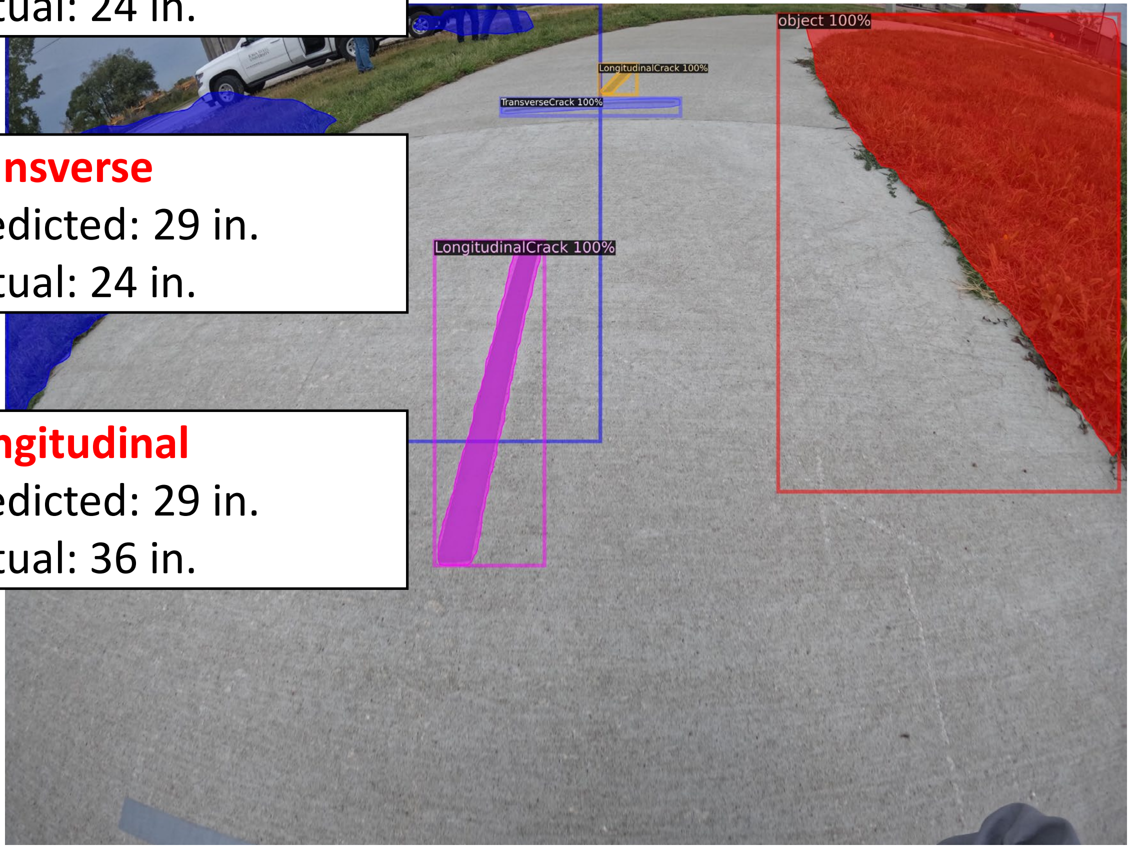
Scale Model vs Actual Length

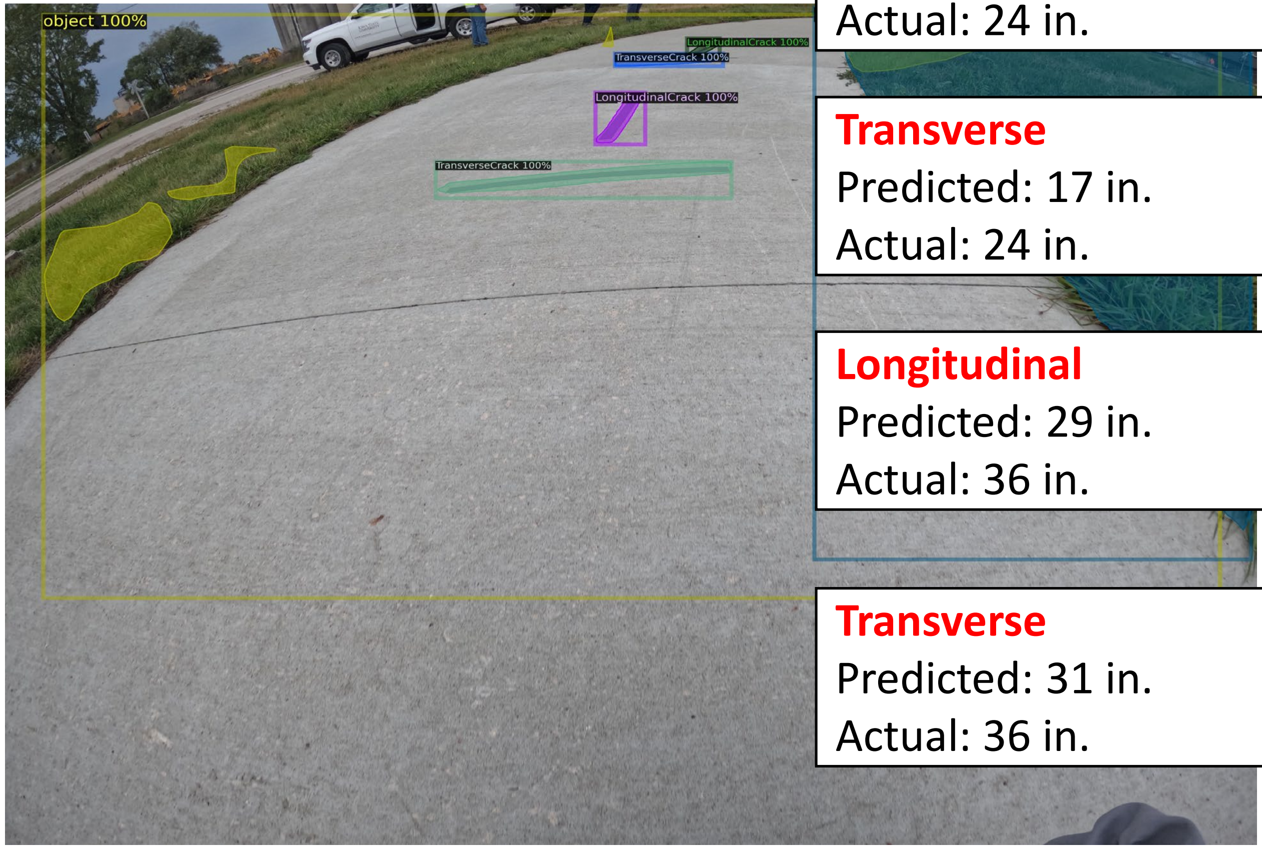
0.5 Sec Interval- 45°

Longitudinal
Predicted: 31 in.
Actual: 24 in.

Transverse
Predicted: 29 in.
Actual: 24 in.

Longitudinal
Predicted: 29 in.
Actual: 36 in.





Longitudinal
Predicted: 33 in.
Actual: 24 in.

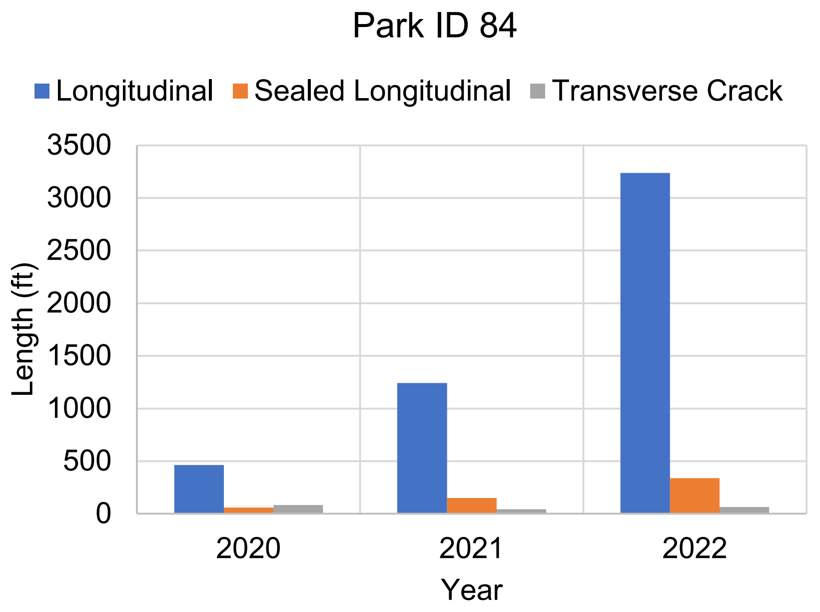
Transverse
Predicted: 17 in.
Actual: 24 in.

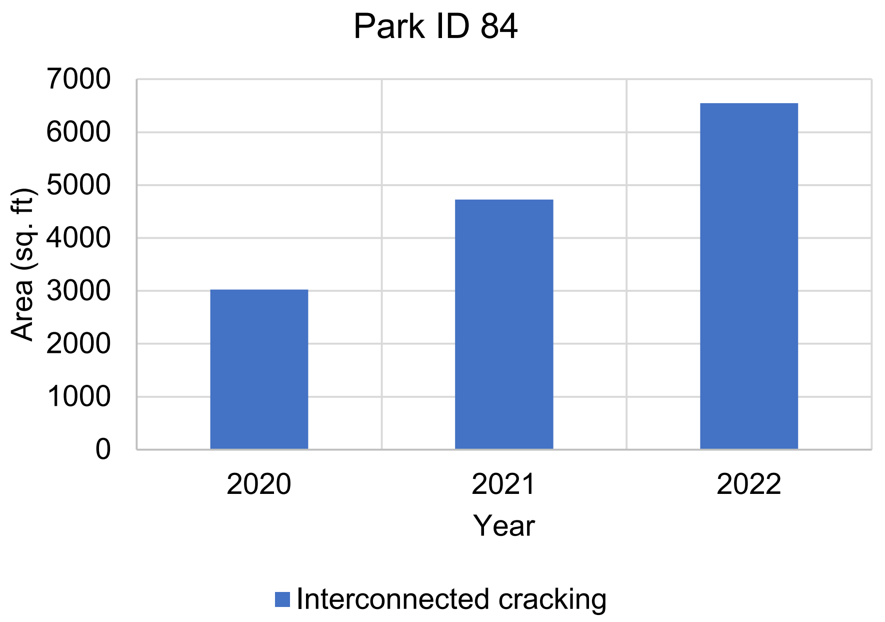
Longitudinal
Predicted: 29 in.
Actual: 36 in.

Transverse
Predicted: 31 in.
Actual: 36 in.

Network-level Deployment

- Model was deployed at the network-level images.
- Distress quantity shown for Park ID 84.





Next Steps

- Developing a Trail Condition Index combining the roughness index and distress data.
    - Requires stakeholder involvement
- Ready for statewide deployment
    - Data collection guidelines to facilitate new agency addition

Site ID	Length (mile)	BIRI	Interconnected Cracking (sq. ft)	Longitudinal (ft)	Patching (sq. ft)	Pothole (count)	Sealed Longitudinal (ft)	Spalling (count)	T-Joint (count)	Transverse (ft)
1	0.39	97	-	35.4	-	0	9.1	0	296	7.5
2	0.49	153	1.7	-	-	0	-	0	502	8.3
3	0.08	55	-	18.7	-	0	7.2	0	122	-
4	1.80	794	4970.9	1671.1	0.7	0	-	0	2	4057.9
5	1.00	492	159.5	93.5	37.7	0	21.6	0	0	6156.2
6	1.43	692	84.3	301.2	0.2	0	17.7	14	2146	1327.6
7A	1.13	597	147.1	1156.3	0.3	0	26.8	10	1020	2314.7
7B	0.31	176	33.1	424.5	-	0	48.9	0	396	251.2
8A	2.46	411	135	3524.8	2.1	0	9.5	34	3546	20371
8B	2.44	110	39.6	839.1	-	2	-	14	3558	669.8
9A	0.57	153	-	495.7	1.4	0	212.6	4	458	153.7

Thank you!

Contacts:

Inya Nlenanya
Research Scientist (PI)
Intrans, Iowa State University
inya@iastate.edu

Zhi Chen
Senior Planner
Des Moines Area MPO
zchen@dmampo.org